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The Solar System

electronics edition • May 1948

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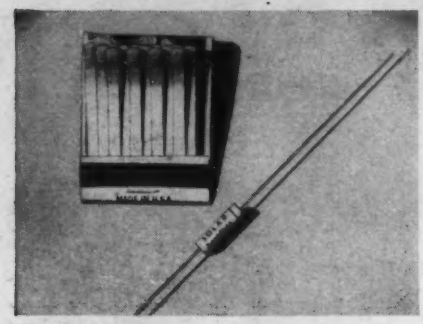

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BUSINESS BRIEFS

By W. W. MacDONALD

Employees in Broadcast Stations and networks totalled 34,720 in 1,260 stations in October last year, according to the FCC. This is an increase of 15 percent since the previous February. These people were paid an average wage of $72.40 for an average 39 hour week. The 7,902 technical employees averaged $91 a week in supervisory jobs, $70 in non-supervisory spots. Technicians in the networks and their key stations were paid about 50 percent higher wages than the average.

ARRL says that in half the cases of television interference so far reported to radio amateurs the fault has been traced to inadequate receiver design or construction. Which reminds us that an informal survey around New York City last year listed causes of tele interference in the following order:

Diathermy
F-M Broadcasting
Radiation by Other Sets
Amateurs
I-F Pickup
All Others

High-Fidelity Amplifiers offered to phono and f-m fans for home use generally put out umpty-ump watts of audio. Few living rooms are large enough to handle such power, even if there are no neighbors to object. How about someone designing a high-quality amplifier that delivers just a watt or two, with resulting savings in power supply and other costs?

Letting the Cat In is now on an electronic basis. W. K. Kearsley of Schenectady has a photoelectric door opener which permits his black cat to enter the cellar but bars felines of lighter color.

Broadcast Station Revenue is very important to television these days, since a large part of television program costs are paid out of sound broadcast profits. In 1946, income went up 8 percent over 1945, but expenses went up 14 percent, as reported here in January. In 1947, according to a preliminary NAB report, revenues hiked up another 8 percent, but expenses gained 9 percent over 1946. The latest word from FCC says the four networks and their ten key stations had net time sales of 72.3 million dollars in 1947, only 3 percent above 1946. A similar index of newspaper revenues and expenses would be interesting, since about half the video stations on the air are owned by newspapers. Radio Corporation of America, whose stake in television is bigger than any other, reported net earnings in 1947 at $1.12 per share of common stock, just double the figure for 1946.

Great Britain's Radio Exports are going great guns. In December 1947 the million-pounds-a-month goal for radio exports was reached for the first time. The 1947 export total was 10.3 million pounds, compared with 8 million in 1946 and 2 million in 1938. Half of the 1947 exports were in radio receivers and phonographs, one-sixth in tubes, and an equal amount in communications, navigational and industrial electronic equipment combined. India is the biggest customer, taking one-fifth of current production.

Electronic Control of Humidity may prove to be a potent protector of health. Two U. of Chicago scientists reveal that germs causing pneumonia, scarlet fever and sore throats are highly vulnerable to the dehydrating action of salt in saliva. Such germs spread through the air, but only if the relative humidity is very close to 50 percent (which incidentally, is a comfortable value for humans). The required accuracy of humidity control can be had only by electronic means.

Cathode-Ray Tubes are mounted too close to the floor in most television consoles, making it hard for a plurality of people to see the show. This is just one of

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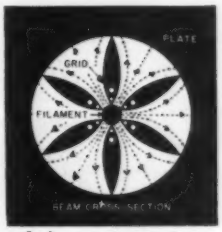

SYMMETRY OF DESIGN . . . enables manufacture of a mechanically rugged tetrode, with self-supporting internal elements. Gassy, inactive, internal insulators, shields and ineffective portions of the elements are eliminated.

PYROVAC* PLATES . . . are incorporated in all radiation cooled Eimac tetrodes. This new material contributes a mechanically rugged plate structure, high resistance to overloads, and exceptionally long life. The use of Pyrovac also enables the elimination of "getters" likely to form troublesome conductive deposits on the inner surfaces of the glass envelope.

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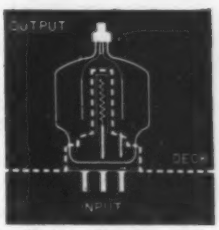
INPUT-OUTPUT SHIELDING . . plus inherent operational stability enables simplification of the associated circuits. Effectiveness of the shielding is so complete that mounting procedures require only that the bottom of the base shell be flush with the top of the deck and grounded.



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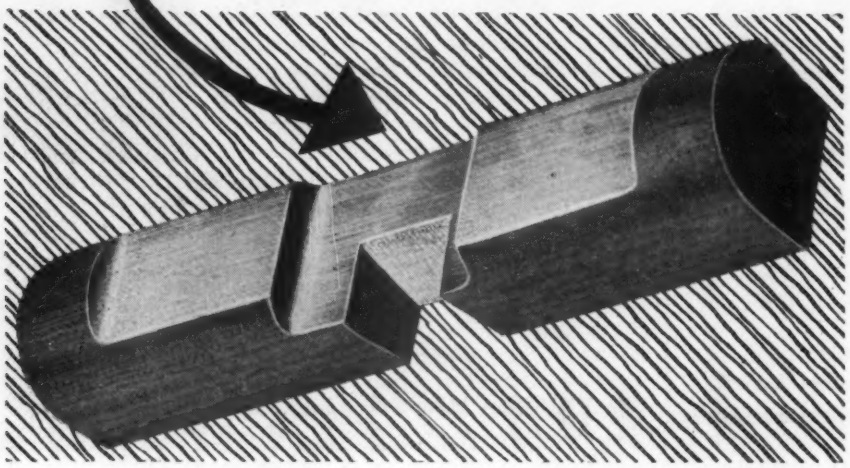

several facts passed along to us by King Electronics' J. H. Robinson, who has made a survey of customer reactions.

Current Quotations: "Price goods too low and the customer questions its quality. Price it too high and you price it out of the market."

Busman's Holiday for many in our business is amateur radio. Of the nine men on ELECTRONICS' editorial staff in New York five have licenses, one will soon reapply, and another is learning the code.

Motorola has 53 amateurs in its Chicago plant . . . 11 inactive at present, 5 building gear, 7 on 2 meters, 5 on 10, 4 on 40, 1 on 80, and the rest operating on several bands.

How about vital statistics on some other plants?

Electronic Autopilots and turbo superchargers made by Minneapolis-Honeywell went into 35,000 B17, B24, B29 and B32 bombers during the war. Each plane carried six amplifiers for the two systems.

Some 1,000 AT11's carried autopilots for training purposes, and the last of the A26's were similarly equipped.

Television Test Equipment required by an adequately equipped installation and servicing organization costs from $4,000 to $5,000, according to Bill Jones of Amie Associates, who should know because he has been in the game for lo these many years.

English and North Irish radio receiver licenses totalled 11,056,900 at the end of 1947, an increase of 278,950 over the previous year. Included in the total were 32,700 television receiver licenses.

Commercial Marine Radar sold by Raytheon since VJ Day totals 450 units.

A New 50-KW Magnetron now undergoing test generates enough power at microwaves to explode tinfoil like a firecracker, scramble eggs in about two seconds.

Television Set Production since the war passed 250,000 sets in February, and the production rate was then at the rate of 430,000 sets a year, according to RMA figures. Two-thirds of the production was in table models.

What's - Wrong - Here - Department: Two papers presented on the same program at a recent meeting of servicemen were titled *How I Made $50,000 Net in Servicing Radios Last Year*, and *I Spent $91,000 to Earn $90,000 in TV Service.*

Auto Radios were installed in 84 percent of the new cars sold during 1947, Sylvania's Frank Mansfield estimates.

Employee Suggestions pay off, and ought to be paid for. Stromberg-Carlson's Lee McCanne tells us that his company has had a suggestion-compensation plan in effect since 1917, and that much of its success is due to the fact that the employee's foreman, as well as the employee, collects on each idea.

Civil Aeronautics Administration hopes to complete installation by July of 396 vhf radio ranges for which funds have been appropriated. Delivery to airlines of 1,000 receivers began last month.

All Over Suburbia we hear the same story: baby sitters can be had if you have a television set. Otherwise you find yourself in the open market with no sales talk. Since video sets are going into homes at the rate of about 40,000 a month, it won't be long before your set must have all channels *and* a 15-inch tube to command any attention at all.

Story Of The Month: E. U. Condon of the National Bureau of Standards tells about two partners who decided to hire a research engineer. Along about 11 a. m. of the first day of his employment one partner said to the other: "Shall we go see whether that research man has discovered anything?" "No," replied his partner, "let's wait until after lunch."

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The Drive-In Theatre Equipment Company, Inc.

Manufacturers of NATIONAL AUTO VOICE In-car Speaker Units

2110-2130 SUPERIOR AVENUE
CLEVELAND 14, OHIO

January 20, 1948

Mr. R. S. Fenton, Sales Manager
Parts Section, Receiver Division
Electronics Department
General Electric Company
1001 Wolf Street
Syracuse, New York

Dear Mr. Fenton:

We would like at this time to express our appreciation for your expeditious handling of our recent rush order for 5¼" PM Speakers.

The speakers used in the Drive-In Theatre in-car units must meet more rigid standards than those ordinarily required commercially. The Drive-In Speaker is subjected to the most adverse weather conditions, and must be able to stand up over a period of years without appreciable impairment of its electrical characteristics. The voice coil form, and the cone proper, must be impervious to moisture or direct rainfall.

It may be of interest to you to know that after a survey of the speaker field, we chose the GE Speaker as the one best able to meet our exacting requirements. The aluminum voice coil form is ideal for our work, since there is no danger of expansion due to moisture absorption. The speakers met Navy type tests such as shock, vibration, temperature, salt spray, and frequency response requirements.

Since standardizing on GE speakers, our customer reaction has been entirely satisfactory.

Very truly yours,
DRIVE-IN THEATRE EQUIMPENT CO., INC.

E. B. Brady
President

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THE LETTER above speaks for itself—simply, forcibly, directly. It tells the story of standard, untreated, G-E speakers from an impartial point of view. Widely varying degrees of dryness and humidity in different sales areas, as well as in the individual home, can affect receiver performance. The aluminum voice coil construction which makes these production line G-E speakers ideal for this rugged, outdoor application can make them a feature of your home receivers. Specify G-E speakers—order today.

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GENERAL ELECTRIC

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CROSS TALK

▸**PREPAREDNESS** . . . It is clear that the people of America have embarked on a program of preparedness for war as the best insurance against war now available. One part of this program is the research and development work in our colleges and industrial laboratories supported by military funds, the annual cost of which is budgeted at approximately one-half billion dollars. A large portion of this amount is currently expended in the field of electronics. Many indirect benefits to the arts of peace will come of this, but the direct and primary purpose of this work is to **keep** the peace by preparing against the contingencies of war. Apparently the importance of the research and development portion of the preparedness program is recognized. But in assessing the adequacy of the program other aspects must be judged.

Unless we can capitalize on research and development, unless we are able to carry the results through to quantity production when needed, preparedness is an empty word. This ability can be gained only by industrial mobilization planning, an essential element of the preparedness program which has not been given the recognition or support it deserves. Whether we like it or not, industrial mobilization must be the concern of our industry as well as every other.

One of the Services has a sizeable staff at work on electronic mobilization planning and is making a determined effort to keep the plan abreast of developments both technically and strategically. The other two Services have few men devoting full time to this work and, so far as we know, the electronic industry represented by the RMA and other groups is not concerned with the problem at all. To attain the objective of electronic preparedness, a sustained and coordinated attack must be made on the problem by **all** members of industry and **all** the Services. Busy as the Services and our industry are today, neither can escape the responsibility for intelligent planning for future wartime military needs.

One pattern has already been established in the aircraft industry, which devotes many hours of excellent talent to the problem of matching production facilities to possible military requirements. The cost is borne by the Services under contracts with the manufacturers and selected research groups. It may be that similar contracts should be written for electronic industrial mobilization planning. In any event, a plan of attack on the problem should be worked out by the industry and Government in close cooperation. To do this, more talent should be assembled on the Government side and the industry will have to reserve sufficient time of its top personnel to work with them. With industry and Government actively collaborating, this chink in our defense can be filled.

A Communications and Electronic Equipment Committee has been established in the Munitions Board. The Committee is made up of representatives from each of the interested Services. Its task is to assist and advise the Munitions Board in establishing a realistic mobilization plan for the electronic industry. This Committee, therefore, should be the central point of contact. A constructive step would be for the Communications and Equipment Committee to request the cooperation of the industry in all phases of the plan. Such a request should be welcomed by our industry.

I. R. E.

National Convention—1948

New York meeting presents 130 papers to an attendance of 15,000, awards to Horle, Seeley, Huggins and 26 fellows. Accelerated activity evident in television, computers, superregeneration, tubes, and nucleonics. Equipment valued at six million shown

EVIDENCE that postwar activity in the field of electronics continues at a level three or four times the prewar level was offered at the National I.R.E. Convention, held March 22–25 in New York. For the second year in a row, I.R.E. put on a show which far outranked the conventions of the old-line technical societies in size and vigor. A program of 130 papers, an attendance of 15,000, and exhibits by 196 manufacturers and government organizations of equipment valued at six milion dollars, provided an overpowering experience for the engineer who tried to take it all in.

When the I.R.E. national convention stepped into high gear in 1947 there were many complaints that the occasion was too elaborate. This year this feeling had given way to resignation that the art was moving so fast there was no way to cope with it. No reporter, or group of reporters, could hope to cover all the sessions or report all the significant advances. What follows here is a fragmentary account of some of the highlights.

Institute Awards

The highest award of the Institute, the Medal of Honor, was conferred on L. C. F. Horle, consulting engineer and head of the RMA Data Bureau. This award recognized the years of service Larry Horle has given the industry in guiding its standardization work, and in coordinating the committee activity and publications of the National Television System Committee and the Radio Technical Planning Board.

The Morris Liebmann Memorial prize went to Stuart W. Seeley, head of the RCA Industry Service Laboratory in New York, for his development of ingenious circuits for frequency modulation, including the discriminator and ratio detector. The recently established prize in memory of Browder K. Thompson, who lost his life in action in World War II, was awarded to William H. Huggins, of the Cambridge Field Station, Air Materiel Command, for his paper on broadband short circuits for coaxial lines.

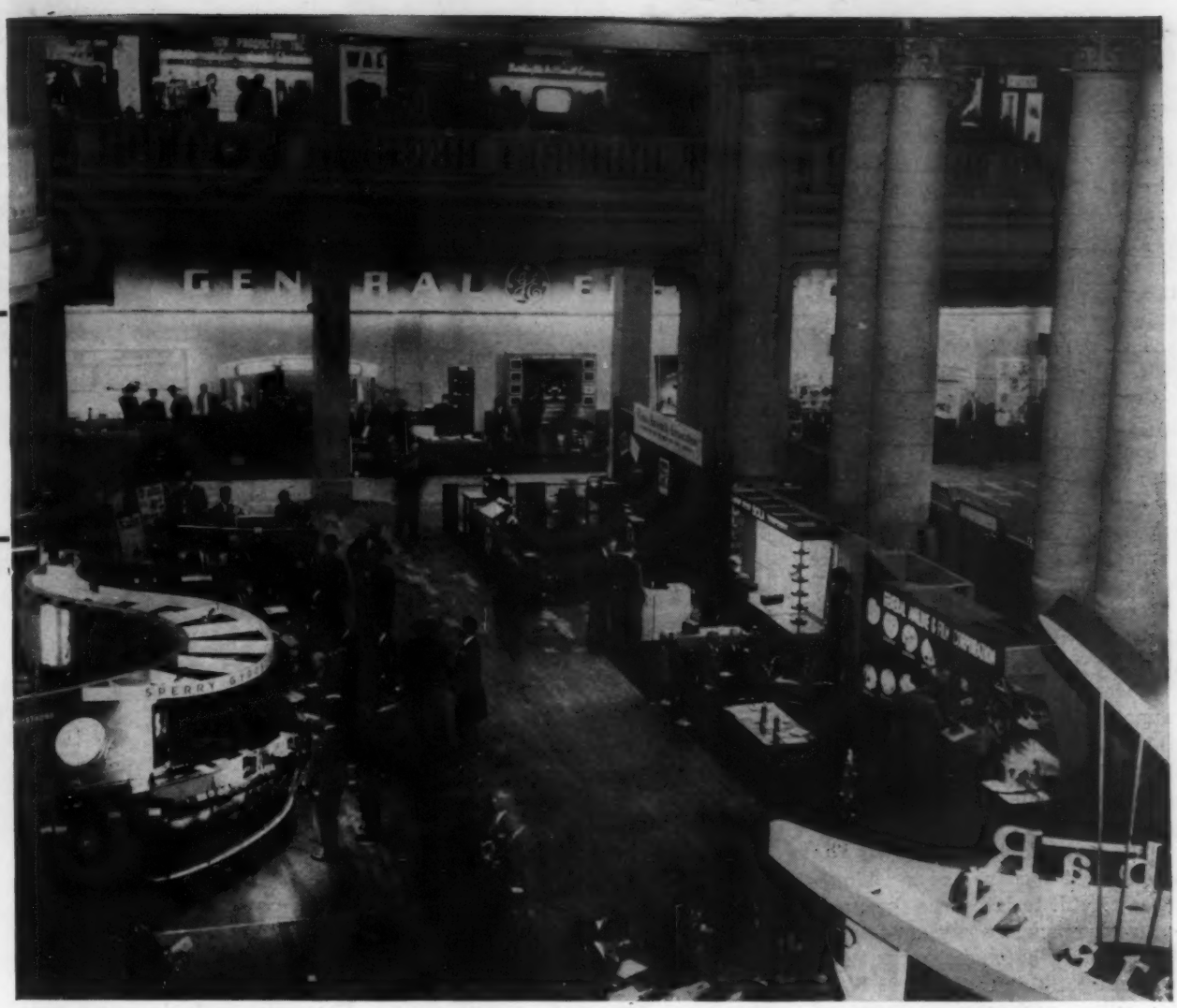
Twenty-six fellowships were awarded to members of the Institute. Reflecting the trend of the times, seven of these awards cited work in the field of television, five in communications, four in general engineering, three in military activity, and two each in measurements, development of vacuum tubes, and navigation.

The President's Luncheon featured a speech by Wayne Coy, newly elected chairman of the FCC. Mr. Coy drew applause for his plea for care in the engineering design of two classes of radio equipment, lack of which may seriously impede the future progress of the art. No new design of a transmitter, he said, can be considered adequate if it neglects the suppression of harmonics, and no receiver design is adequate if it neglects suppression of oscillator radiation. He questioned the adequacy of a television allocation plan restricted to city districts, and predicted that all the channels allocated to the 140 metropolitan districts would be assigned by the end of the year. Mr. Coy announced that the FCC had given type approval to the first Citizens Radio equipment, that production was underway and that a simplified licensing procedure was being worked out.

The Annual Banquet was addressed by W. R. G. Baker, outgoing president, who drew the parallel between the frontiers of territorial expansion and the frontiers of electronic science. Noting that nucleonics and electronics were inextricably interwoven, he reminded his audience expanding knowledge is fruitless and dangerous unless it is available to everyone who can use it for human betterment.

A. N. Goldsmith, noting that the Institute's membership had doubled between 1927 and 1937, quadrupled between 1937 and 1947, gave evidence that I.R.E. activities are now big business. One hundred thousand man hours of effort were expended in I.R.E. Committee work in 1947, representing an investment on the part of the members and their employers of nearly a million dollars.

Contrasting with present activity, John V. L. Hogan outlined the frontiers of the industry in 1912,



View of some main floor exhibits during a lull in traffic. Over $6,000,000 worth of electronic equipment was displayed on the three floors and balcony of Grand Central Palace

when the spectrum extended from 50 to 1500 kc, radio-frequency amplification was unknown, and the triode vacuum tube was not popular because it required batteries. Max Balcom, president of RMA, predicted an eventual expansion of the industry to an annual value of goods and services of five billion dollars.

Organization of Technical Program

The 130 technical papers were arranged in quintuplicate sessions on the following topics: frequency modulation, networks, systems, navigational aids, antennas, amplifiers, tube design, superregeneration transmission, nuclear studies, industrial electronics, components, supersonics, television, synthetic crystals, broadcasting and recording, tube manufacture, measurements, computers, propagation, microwaves, receivers and active circuits.

The first paper on the program, by H. B. Richmond of General Radio, discussed the position of the engineer in the electronics industry. Approximately one-quarter of all college trained engineers are in the field of electrical engineering, and the majority of this group are in electronics and communications.

A 20-fold increase in available electronic engineers is to be expected in the twenty year period from 1938 to 1958. Even in the next 2 years, a four-fold increase may occur. This is in itself not cause for concern, but it is certain that research jobs cannot be found for all the recent graduates now demanding this type of work. Work in design and production engineering, maintenance and operation should be plentiful, however.

Mr. Richmond's researches indicated that the average B.Sc. graduate starts at about $250 per month, somewhat higher if he has had useful military experience. An M.Sc. degree is worth about $50 additional to start, a D.Sc. or Ph.D. about $100 over a B.Sc. Engineers with doctors' degrees tend to stay in research, scientific and design engineering jobs longer than those with lower degrees. Most of the engineering administrative and sales engineer jobs are filled with lower-degree men. A research man in electronics must be supplied with about $15,000 worth of equipment, and is likely to cost his employer

about $10,000 a year if he is to be effective.

A new type of beam tube intended to serve as a frequency-modulation detector was described by Robert Adler of Zenith. The tube performs the functions of a grid-bias limiter and a discriminator, using a single tuned circuit and an ingenious beam structure within the tube. The limiting occurs instantaneously, since there is no energy storage in associated circuits. A beam-forming cathode at r-f ground passes a beam through a positive slot aperture and thence to a control grid connected to the i-f input signal. The electron beam, emerging from the grid, passes another positive slot aperture through a second grid and thence to the anode.

If the control grid is negative, the trajectories of the beam electrons are curved back toward the cathode in such a way that they cannot pass through the second slot. At positive grid potentials however, the electron beam passes through to the anode. The limiting action is extremely sharp and occurs at an input signal of about one volt. The second grid is connected to a single tuned circuit to introduce the quadrature component necessary for f-m detection. The audio output appears directly at the anode. Since the output-vs-frequency curve of the gated beam tube has no negative slope within several hundred kc of the midfrequency, the tuning of the receiver is simplified.

Broadcast engineers Glenn Koehler and Harold Engel of WHA, Madison, Wisconsin, measure distortion and noise in an audio signal while Bill Broughton of GE (at left) explains the operation of the equipment

Simplified Selective Sideband

Another paper which excited particular interest was presented by D. E. Norgaard of General Electric, describing simple methods of selective sideband transmission and reception. Using the wideband phase-shift circuits described by R. B. Dome in ELECTRONICS in 1946 (December, p 112), it has been possible to construct simple and practical single sideband systems, useful with any type of modulation (a-m, f-m or p-m, with the carrier suppressed, attenuated or exalted). Moreover restriction of audio bandwidth does not occur; response flat within 0.1 db from 30 to 15,000 cps is possible in single sideband operation. Low-level modulation is used, followed by linear amplification.

In the receiver, conventional circuits are used up to the second detector. At this point two detectors are used in conjunction with a locked-in second local oscillator. The outputs of the detectors drive Dome phase-shift networks, producing sum and difference frequencies corresponding to the respective sidebands. Two audio amplifiers develop these signals separately. One of the most interesting practical applications suggested was the use of the two sidebands in conventional broadcasting to supply binaural reception, two microphones controlling each sideband independently. In shortwave communication, where selective fading is severe, single sideband operation produces a substantial improvement in intelligibility.

Low-Noise Amplifier

An ingenious double-triode amplifier originally developed at the Radiation Laboratory in 1944 was described for the first time by Messrs. Wallman, Macnee and Gadsden of MIT. The two triodes are connected in cascade, the first tube operating as a normal grounded-cathode stage directly coupled to the cathode of the second, which operates as a grounded-grid stage. Used as i-f amplifiers, each stage has a single-tuned circuit in its input, and the first stage has in addition a small inductance between grid and anode. The second stage, being grounded grid, presents a very low impedance to the plate of the first stage. As a result the gain of the first stage is about unity and its operation is correspondingly stable over a wide band. The gain of the grounded-grid (second) stage is about equal to the product of its transconductance and load resistance, whereas the overall gain is the product of the first tube transconductance and the second tube load resistance.

The overall power gain of the two tubes is of the order of 200 using typical tubes and this makes the noise contribution of the following stages negligible. Typical tubes used are a 6AK5 connected as a triode for the first stage and one-half of a 6J6 double triode as the second stage. Typical stages operating at mid frequencies of 6, 30 and 180 mc have exhibited noise factors 0.25, 1.35 and 5.5 db above theoretical respectively, at bandwidths of 2, 12 and 30 mc respectively. One of the lowest noise figures ever obtained in a 10-cm radar receiver, 8.7 db above theoretical, was achieved by the authors

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The radiator for a big-dish antenna displayed at the IRE meeting is examined by George McIntire of W1EJ, Winchester, Virginia

using a cascade amplifier of this type at 30 mc.

Diode Rectifier Motor Control

Thyratron motor controls to secure a high value of torque at low speeds in motors, now commonly used in machine tool drives and other industrial applications, can be improved to the extent of a 50 percent increase in torque, by the circuit described by W. N. Tuttle of General Radio. In this circuit a variable transformer (Variac), a choke and a full-wave vacuum diode rectifier are used to feed the armature of a d-c shunt motor. The low cost of vacuum full-wave rectifier tubes makes it possible to provide current capacity sufficient for instant starting, and the space requirements for the control are considerably less than that of the equivalent thyratron control. A one-third h-p motor can be controlled by such a circuit in a case 9 by 5 by 12 inches. By reversal of the armature current it is possible to provide dynamic braking in addition to speed control. A constant increment in speed from no load to full load is obtained over the full range of speed control, which may cover a range as wide as 20 to 1.

Two well known figures in radio, Knox McIlwain and Harold A. Wheeler addressed themselves to an old problem: Can radio waves be transmitted deep in the earth? Calculations had indicated subsurface exploration as deep as 5,000 feet might be possible by reflection of radio waves from strata, assuming a system amplification of 150 db. The Bureau of Mines had received radio waves at broadcast frequencies several hundred feet below the surface under circumstances which indicated direct passage through the earth. A joint investigation by Seaboard Oil Company and Hazeltine was set up to determine what might be done, using wave frequencies from 0.5 mc to 1,000 mc. Initial successful transmission through 600 feet of earth proved impossible to repeat. Later it was noted that the first observation had been made following a prolonged dry spell, whereas later attempts had followed heavy rain fall. A final determination was made by lowering a transmitter and receiver through separate drill holes, with the holes capped so that any energy detected would have to pass through the ground. Variations in loss as high as 1 db per foot were observed between layers of shale and sand, and the variations were closely correlated with changes in structure. Ground moisture introduces such losses that it was concluded that this method of geophysical prospecting was impractical. The method has some chance of success when used to locate water in very dry regions, however.

New Microwave Oscillator

E. D. McArthur of General Electric described a new type of triode, now in the development stage, which may prove useful as a generator of microwaves for such purposes as local oscillation and signal generation. The tube, called a dyotron, is a conventional triode containing a bypass capacitor of about 70 $\mu\mu$f within the envelope connected directly between grid and cathode, thus effectively removing any r-f potential between grid and cathode. The tube then becomes a two-terminal device, so far as r-f is concerned. Oscillation occurs as a result of the penetration of the grid-anode field through the grid structure so that it affects the cathode current. No external feedback circuit is required. D-c bias may be applied between grid and cathode to regulate the frequency of oscillation.

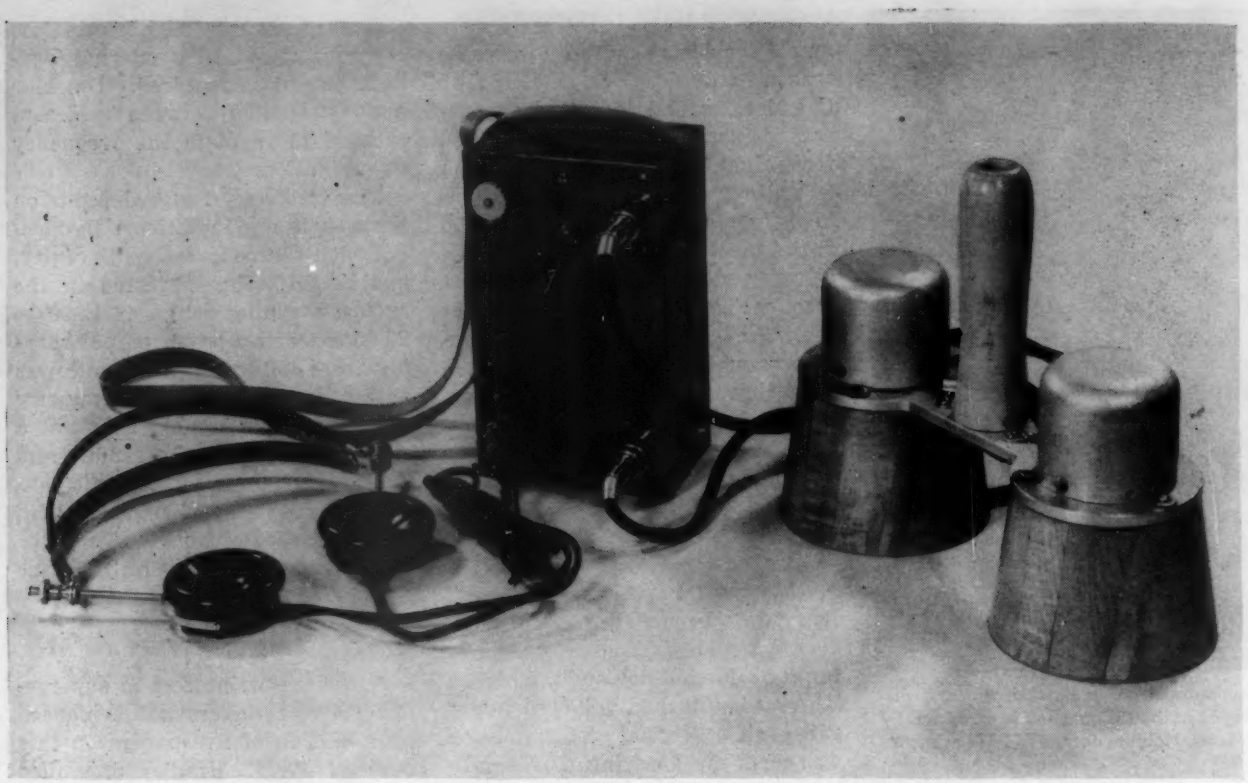
The frequency range depends on the transit angle relations. By placing such a tube in a coaxial cavity, and by adjusting a piston in the cavity, a tuning range of 1,800 to 2,800 mc, with a power output varying from 100 to 350 milliwatts was obtained, with excellent frequency stability. In a signal generator, a single tube covers the range from 1,400 to 3,200 mc. Electronic tuning is possible by changes in grid bias at a rate of about 0.5 mc per volt, over a total range of 3 to 4 mc at 1,000 mc.

Superregeneration

A rebirth of interest in superregenerative receivers was evidenced by a session of five papers on this subject. W. E. Bradley of Philco presented a unified theory of this circuit drawing a causal connection between the shape of the time variation in the conductance of the tube, determined by the shape of the quench waveform, and the resulting selectivity curve. A Fourier transform is employed to convert from the time function to the frequency function. An example of this technique, the design of the Fremodyne circuit for f-m reception, was given by B. D. Loughlin of Hazeltine. Harold Wheeler reviewed the recent history of this circuit and opined that new uses would be found for it, now that the basic theory is better understood.

The growing importance of electronics in nuclear studies was reviewed in two sessions, and announcement was made of the cooperative effort of several technical societies to set up a uniform glossary of nuclear terms.

A new branch of communications technology, christened cybernetics, was discussed by Norbert Wiener of M. I. T. This system brings the nervous system and its psychological attributes explicitly into the communications system as a functional element and studies the capacity of the individual to assimilate and use the information offered by the system.—D.G.F.



Experimental model of a 32-kc pulsed frequency modulation blind guidance system. Headphones can be replaced with bone conduction unit, and use of 65 kc allows smaller double-transducer assembly (see Fig. 1).

BLIND GUIDANCE

To investigate the possibilities of developing artificial devices to aid the military blind, the Committee on Sensory Devices was organized in 1944 under the jurisdiction of the Office of Scientific Research and Development. The Haskins Laboratories of New York City was selected by the Committee on Sensory Devices to serve as a central laboratory for the Committee in guiding the efforts of various groups doing the research and development and also to carry on tests with blind subjects. The Stromberg-Carlson Company was one of three industrial organizations chosen to develop blind guidance devices using ultrasonic echo-ranging techniques. In September 1945, the Committee on Sensory Devices was transferred to the National Research Council and the financial support of the research program was taken on jointly by the Surgeon General of the War Department and by the Veterans Administration.

From a paper presented at the 1947 National Electronics Conference in Chicago.

While the idea of a person's carrying around a portable radar-like device originally seemed rather fantastic, there was the precedent of the bat's use of an acoustic form of echo ranging[1,2] and of a blind person's use of audible sounds to locate walls and other fairly large obstacles.[3]

System Limitations

Although at first the form of the guidance device was only loosely defined, it was natural to assume that it would be something like a flashlight which the user could point in various directions. The signal would probably be some audible indication of the distance to the obstructing object. The maximum distance range that seemed desirable changed with experience.

At first, the tentative specifications called for a maximum range of at least twenty-five feet, and fifty feet if possible. Later experience with systems which did have a range of fifty feet or more showed that there was a large amount of information about distant objects that was of no immediate use and actually caused confusion. A blind subject, for example, walked with much more confidence if the guidance device gave no indication of objects beyond eight feet than he

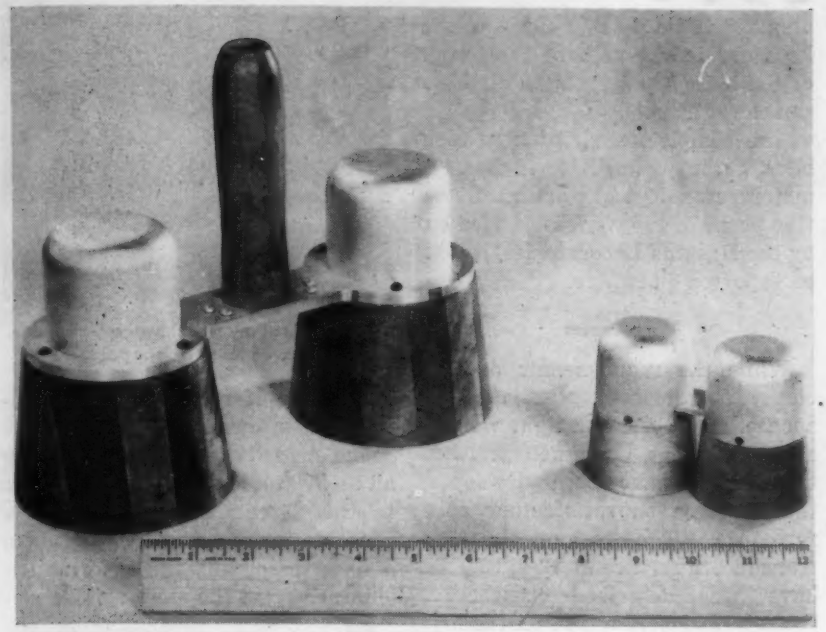


FIG. 1—Magnetostriction transducers used in the 32-kc (left) and 65-kc devices

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Portable radar-like device employing pulsed frequency modulation gives a single audio frequency tone corresponding to any given obstacle distance. Simultaneous echoes from different distances are identified by combinations of individual tones. Complete experimental equipment weighing 5½ pounds operates at 65 kc to detect obstacles up to 30 feet

by ULTRASONICS

did if he had to sort out and interpret information indicating many distant objects. Whether a prolonged training period would make it possible for the subject to ignore the distant signals, except when they were of real interest, is open to question.

A fundamental limitation of any echo-ranging system is the fact that the type of information which a blind person expects from a guidance device can not always be obtained by echo-ranging. An open door, for example, is difficult to find from the opposite side of a room. Unless the beam of ultrasonic sound is very narrow, the echoes from the posts at each side of the door mask the lack of an echo between them. A closed door, it would seem, could not be found at all. Conditions that are hazardous are sometimes difficult to find by echo-ranging, since not all hazards are caused by the presence of obstacles. An open manhole, a sudden step-down or a curb are as dangerous as solid obstacles, yet it is difficult to identify either the hole or the step-down by echo-ranging. From the point of view of acoustic field theory, there is always a scattered wave whenever there is a discontinuity of any kind

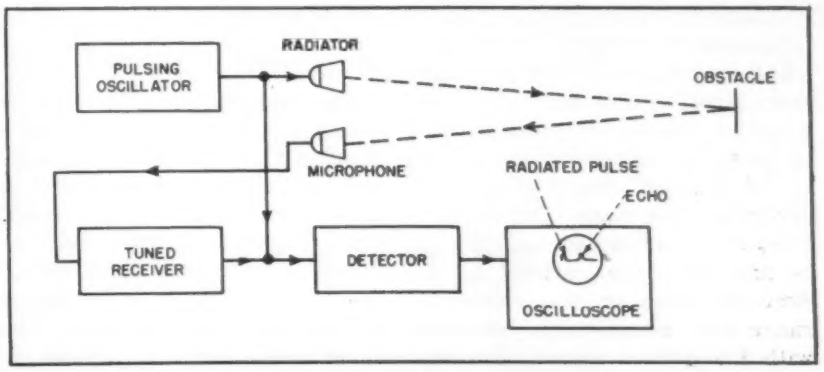

FIG. 2—Block diagram of a simple pulsed blind guidance system

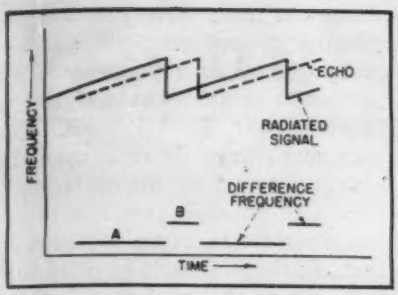

FIG. 4—Graphical representation of the sawtooth frequency modulation system

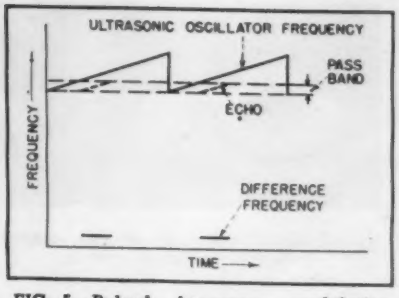

FIG. 5—Pulsed frequency modulation system employing ultrasonic oscillator

kilocycles and the total length of the sweep is equivalent to 18 feet. To obtain this photograph, the camera shutter was left open for the entire time it took the subject to walk up to the transducers.

First-Echo Pulse System

One type of pulse system often proposed for blind guidance causes the outgoing pulse to be initiated or triggered off by the echo. In such a system the repetition rate gives an indication of the distance, a fast repetition rate indicating a nearby object and a slow repetition rate indicating a distant object. This type of system should operate satisfactorily if only one echo is received for each radiated pulse. However, it often happens that echoes from more than one object are received in a single period. For example, if three echoes return after the first pulse, each of these three echoes will trigger off a pulse, and for each of these pulses there will be three more returning echoes. It is apparent that there results a continual multiplication of the number of pulses sent out so that the system quickly saturates and no useful information is obtained.

A system has been developed to avoid this difficulty by responding to the first echo only. It has a repetition rate that is a function of distance. This short-range obstacle-location system meets the following specifications: (1) the device responds to the first echo only; (2) the presentation is tactile; (3) the range is limited; (4) there is no detectable signal when no echo is received; (5) the frequency of the tactile presentation decreases with distance.

The range indication as given by the repetition rate varied in the first-echo pulse system developed from about 30 pulses per second for nearby objects to about five per second for distant objects. The maximum range could be limited to any value between six and 20 feet. This system, however, had two important fundamental limitations.

First, the frequency range of the distance indication was insufficient for tactile presentation. The maximum repetition rate could not be increased since the period must be sufficiently long for all echoes to return in the same period in which the corresponding pulse was radiated. Reports from the testing psychologists indicate that a frequency range of 20 to 200 cycles per second should be provided for tactile presentation.

The second limitation was the effect of fluctuation of the echoes mentioned earlier. These fluctuations produced an instability in the signal which made it difficult to interpret. As the echo flickered, there was an occasional period in which the significant echo did not appear. In such event, the radiation of the next ultrasonic pulse did not take place until the normal idling period had passed. The pulses were thus unevenly spaced, making it difficult to recognize any definite repetition rate.

To be sure that the range indication will be independent of the way in which the echoes might flicker, the indication of the distance to the reflecting obstacle should be definitely established by one sequence of events consisting of the radiation of the ultrasonic signal and the return of the echo. It should not be necessary for subsequent cycles of events to repeat consistently. In an oscilloscopic presentation, the position of the echo on the horizontal axis is fixed by the time that elapses between the radiation of the pulse and the return of the echo. No matter how violently the amplitude of the returning echo may fluctuate, the position of the echo on the oscilloscope remains substantially unchanged.

F-M Systems

A similar independence of range indication and echo amplitude can be attained with a frequency modulation ranging system. In such a frequency modulation system, the frequency of the ultrasonic signal is varied cyclically as a function of time. Since the echo is delayed by the time required for the signal to travel to the reflecting object and back to the transducers, there is a difference between the echo frequency and the frequency of the ultrasonic oscillator at the time the echo returns. This difference in frequency is also a function of the distance to the reflecting object. If the rate of change of frequency is chosen properly, the difference frequency can be made audible by mixing the oscillator signal and the echo in a nonlinear circuit. To de-

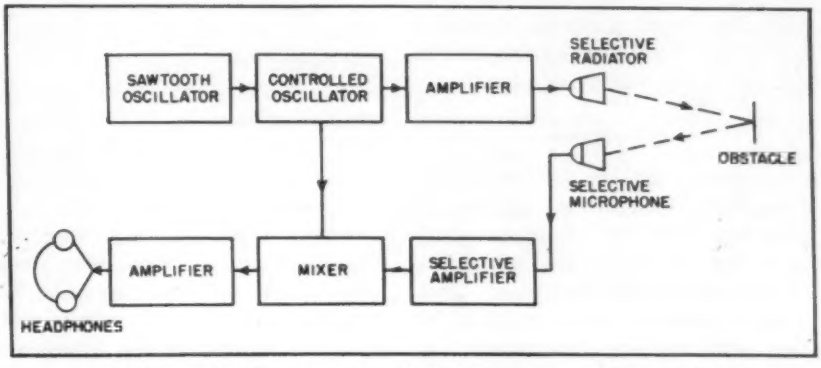

FIG. 6—Block diagram of the pulsed frequency modulation system

in the path of the sound wave. The wave scattered back from a step-down, however, is so small that it might easily be mistaken for the wave scattered from a crack in the sidewalk.

Signal Presentation

Even if the desired information can be obtained by echo-ranging, there is still the problem of the presentation of this information to the blind subject. With the sense of sight no longer available, the information must be presented to one or more of the remaining senses. The most obvious method of presenting direction is to allow the transducer unit to be held in the hand so that the subject can scan his environment with the projected ultrasonic beam. When an obstacle is detected, its direction is thus the direction in which the transducer unit is pointed. This method is used in all systems described here.

Perhaps the most obvious method of distance presentation is aural. However, other types of presentation are possible and in some circumstances may be more desirable.

Ultrasonic systems have been built that present the range information either aurally or tactually. Some of these systems have been modified so that the information is presented by direct electrical stimulation; for example, a controlled shock. Of the three methods, the most information can be presented aurally. However, blind subjects prefer not to use earphones since they interfere with normal hearing cues. While the use of a bone conduction receiver may be the most satisfactory compromise, the decision between types of presentation can only be made after tests with blind subjects.

A number of difficulties exist in ultrasonic systems, the main one being specular reflection of sound from large, smooth surfaces. Such a surface, unless it contains irregularities that scatter the sound, can be detected only when it is oriented normal to the beam. Fortunately, most flat surfaces encountered can be detected by the scattered sound. Ambient noise in the ultrasonic range can, occasionally, interfere with the desired signal. For example, the jingling of keys, if the keys are in the path of the beam, or the blast of air from an air hose can cause trouble.

The complete evaluation of any blind guidance device is in itself a major psychological problem. Since this phase of the work is carried on by the Haskins Laboratories, it will be reported elsewhere.

Transducers

While the requirements of efficiency, bandwidth, transient response, small size and light weight are stringent, magnetostriction transducers have been developed that have given satisfactory performance. The magnetostriction transducers for use at 32 kilocycles have been described elsewhere;[4] these transducers were satisfactory for experimental use but would be too large for a practical device. Magnetostriction transducers for use at 65 kilocycles have also been developed. These are similar to the 32-kilocycle transducers but are correspondingly smaller so that their directional characteristics are approximately the same.

Separate but identical transducers are used for radiator and microphone. The transient response of the units does not permit use of a single unit for both functions. Figure 1 is a photograph of the double transducer units for 32 kilocycles and for 65 kilocycles.

The beam width of a single transducer is about 6.5 degrees at the half-power point. The on-the-axis sensitivity as a microphone is 60 to 70 decibels below one volt per dyne per square centimeter. The bandwidth of a single unit is 300 to 500 cycles. In a pulse ranging system, this bandwidth is sufficient to resolve two objects spaced from 1⅔ feet to one foot apart.

Simple Pulse System

The simplest type of pulse echo-ranging system is shown in Fig. 2. A pulsing oscillator generates short pulses of ultrasonic frequency separated by a constant interval of time. The distance from the transducers to an object which reflects the ultrasonic pulses is determined by measuring the elapsed time between the radiation of a pulse and the return of its echo. For studying the properties of ultrasonic sound fields it is convenient to use an oscilloscopic presentation similar to the A-scan of radar. Such a presentation is, of course, useless to a blind man, but the information obtained from the simple pulse systems has been invaluable in the laboratory. By means of such systems it has been possible to measure the magnitude of the scattered wave from a sharp step-down.[5] It was also apparent, after working with the pulse system for a while, that the echo from an object as small as a fine thread might, under certain circumstances, be greater than the echo from a large, flat wall. At 65 kilocycles, an ordinary sewing thread at a distance of a foot or two and held normal to the beam produces an easily detectable echo, while a very smooth wall at an angle to the beam may give no detectable echo at all. Inhomogeneities in the air cause the echoes from objects ten or twenty feet away to fade and flicker, and at 30 kilocycles the echo from a wall about thirty feet distant may vary from zero to a strong echo that fills the whole oscilloscope screen. Echoes from objects having a complex shape are even more susceptible to flickering than the echoes from a simple object such as the flat wall. Sound reflected from various portions of the complex object may reinforce or cancel as the atmospheric conditions vary, and in such an instance it takes a very small change in the properties of the acoustic path to cause violent fluctuations of the echo. Most unstable of all is the echo from a complex moving object. Figure 3 shows the fluctations that occur as a person walks toward the transducers. The frequency is 32

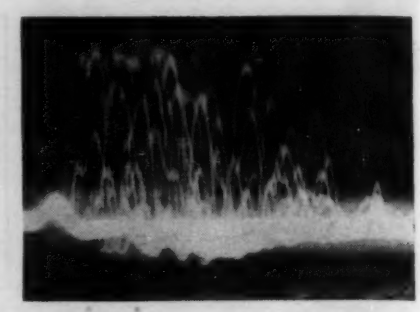

FIG. 3—Oscillogram showing echo fluctuations as a person approaches

Vacuum Furnace Control

Tungsten heaters are automatically safeguarded against burnout due to excessive gas pressure. A thermistor, used as the sensing element, operates a calibrated indicating meter and a relay. Unit is used in the manufacture of electron tubes

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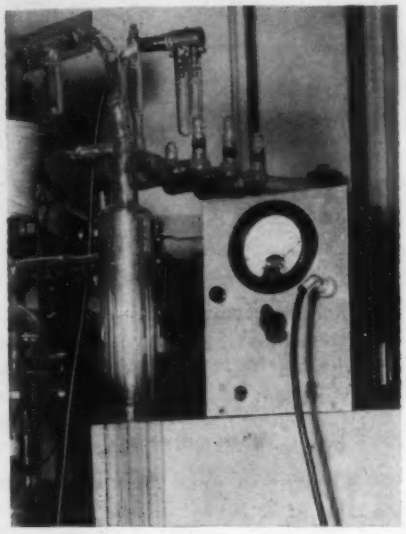


Vacuum furnace control unit, installed adjacent to the system's diffusion pump

WHEN OPERATING a high vacuum electric furnace the tungsten radiant-heating elements must not be turned on until pressure is low enough to permit safe operation. Also, power must be instantly turned off in the event that pressure rises during operation.

Both of these functions are automatically handled by the electronic control illustrated.

Design Details

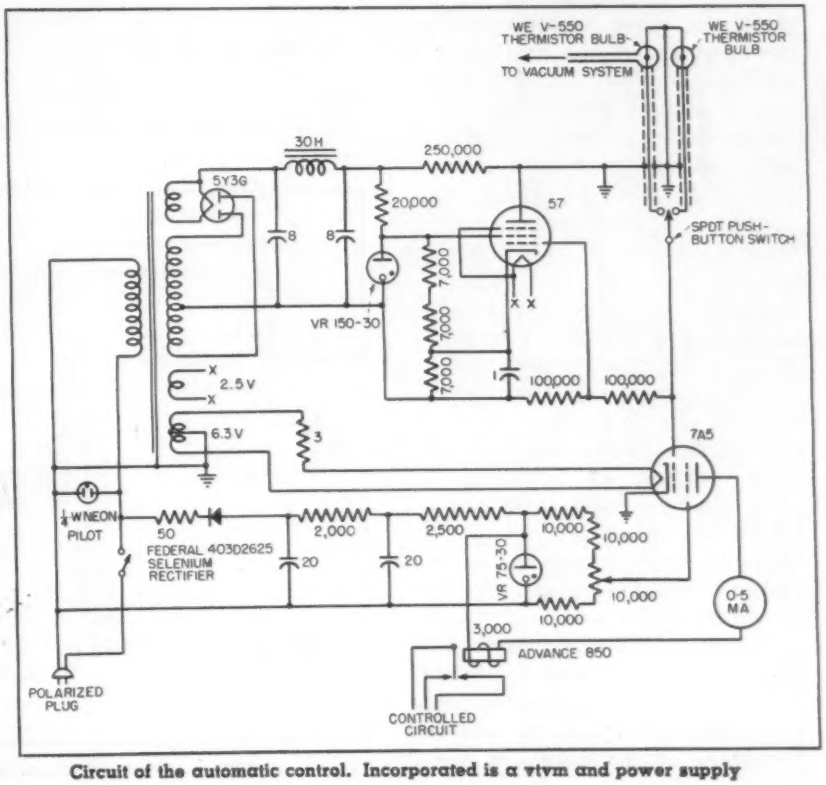
When a thermistor is suitably mounted in a tube connected to a vacuum system and heated by a small constant current its equilibrium resistance depends on the heat taken away by convection. As the molecular concentration in the furnace is reduced by pumping, convection heat loss drops and temperature rises. The thermistor undergoes a corresponding resistance change which can be calibrated in terms of vacuum.

In this control, two identical and similarly-mounted thermistors are used. One is mounted in a tube which has been pumped down to approximately 10^{-6} mm Hg and sealed off, and serves as a standard. The other is connected to the vacuum system of the furnace diffusion pump.

Operation

In operation, the vtvm is adjusted to full scale with the pushbutton pressed to place the sealed-off thermistor in the circuit. Then, when the button is released, the measuring thermistor is connected and vacuum is read on the meter scale in terms of the vacuum sealed in the calibrating thermistor.

A small non-linearity in the vtvm is used to provide some compensation for crowding of the vacuum scale which is ordinarily found at the high end of the range. The relay in the circuit with the indicating meter provides the automatic switching that turns on heaters at a pre-determined vacuum level and turns them off again if that level is later exceeded.



Circuit of the automatic control. Incorporated is a vtvm and power supply

termine the distance to the reflecting obstacle, the only requirement is that the duration of the audible signal within one repetition period be great enough to permit recognition of the pitch. The duration of the signal can thus be as short as 40 milliseconds for the recognition of the pitch of signals above 100 cycles per second.[6] It will not matter if, in the next repetition period, the echo fades out completely, for the accurate interpretation of the range signal does not depend upon the consistent repetition of the signal in every period.

The most common types of modulation used in f-m ranging systems are sinusoidal and sawtooth modulation. Sinusoidal modulation results in an unnecessarily complex signal, and consequently will not be considered here. Sawtooth frequency modulation is illustrated in Fig. 4.

The radiated signal is represented by the heavy line that varies up and down in frequency as a function of time. The echo, shown by the dotted line, is delayed by the length of time required for the radiated signal to reach the reflecting obstacle and return. The difference in frequency between the radiated signal and the echo is shown as the solid lines *A* and *B*. It is seen that there are present in the beat note two frequencies. Frequency *A* rises as the distance between the radiator and the obstacle increases while frequency *B* becomes less. If we call the repetition period T and the delay time Δt, the beat note corresponding to an echo which is delayed by a length of time Δt will be indistinguishable from the echo which is delayed by an interval equal to $(T-\Delta t)$. The problem of finding one's way about with any ranging device is difficult enough without forcing the user to interpret contradictory signals.

PFM System

A system known as the pulsed-frequency modulation system or pfm has been developed to eliminate the confusing characteristics of the f-m systems described above. Figure 5 shows the way in which the pfm system functions. The ultrasonic oscillator varies in frequency following the sawtooth

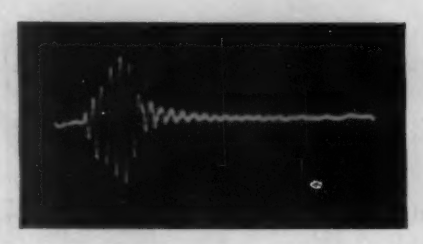


FIG. 7—Oscillogram of audible signal from pfm guidance system

curve. The frequency band of the sound actually radiated and received is limited by the pass band of the ultrasonic transducers. The received echo, then, is a pulse of utrasonic energy of changing frequency that lasts about 50 milliseconds. A block diagram of the pfm system is shown in Fig. 6. The echo and the original oscillator frequency are combined in a mixer stage and the audible beat note is fed into a headset. The beat note appears as a series of pulses, as illustrated in the oscillogram in Fig. 7.

In the pfm system there is a single audio frequency corresponding to any given distance, and as long as the repetition rate is sufficiently slow that even the most distant echoes return before the new repetition period starts, there is no contradictory information supplied. Even when echoes from different distances arrive during the same period, the subject can learn to identify the different distances by listening for the various individual frequency components in the audio output. It is much the same sort of situation as learning to identify the notes of a musical chord, with the exception that in the output of the pfm system the low frequencies that correspond to nearby objects are heard first, and the higher frequencies that correspond to the more distant objects are heard slightly later.

The photograph shows an experimental version of the pfm system. The case houses a four-tube receiver, a six-tube transmitter, and batteries. Subminiature tubes are used in all positions except the utrasonic output stage which employs a 3Q4. Filament drain is 370 milliamperes at 1.5 volts; plate drain is approximately 5 milliamperes at 45 volts. Total power demand is about 0.75 watt. The weight of the complete system, including transducers, headphones and batteries, is 5½ pounds. This particular system was designed to operate near 30 kilocycles. The maximum range depends upon the size and nature of the obstacle. A person in an open area can be detected at distances up to about 30 feet. In the judgment of blind subjects it was the most useful of the systems tested for actual outdoor situations.[7]

The two most obvious disadvantages of this model of the pfm system were the size of the transducers and the use of headphones. These disadvantages have, to a large extent, been overcome in a more recent model that operates at 65 kc and uses the smaller transducers shown in Fig. 1. A bone-conduction receiver is used instead of headphones. Although this model has not been completely tested by Haskins Laboratories, its performance appears to be at least equivalent to that of the 32-kilocycle model.

Although these units are larger than hearing aids and their power requirements are greater, neither their size nor their power requirements are unreasonable, especially at 65 kc. The information provided by such an echo-ranging system is different from that provided by a Seeing-Eye dog or a cane. Consequently the usefulness of such a system must be evaluated both by psychological tests and extensive use of the system by blind subjects. It is entirely possible that the information provided by any echo-ranging system may not be sufficiently valuable to a blind person to outweigh its inconvenience.

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Simplified Single-Sideband Reception

Accessory designed for use with a conventional communications receiver exhibits advantages when receiving ordinary code signals, as well as single-sideband phone. Selectivity is approximately doubled by employing a demodulating oscillator, balanced detector, two 90-degree audio phase-shift networks and a low-pass filter

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ATTENTION has recently been drawn to 90-degree wideband audio phase-shift networks as a means of generating single-sideband radio signals.[1,2] Filters of the R-C type, such as those described by Dome[3], are simple and inexpensive to make. Moreover, radio transmitters incorporating them are flexible and easier to adjust than the conventional variety using sharp band-pass filters. It is reasonable to expect, in the light of these and other developments[4,5], a re-evaluation of the possibility of applying single-sideband transmission to a much wider group of radio services (aircraft, police, military and amateur) than those at present enjoying its advantages.

Practical 90-degree networks make possible an equally important simplification in single-sideband receiving technique. An arrangement is described in this article whereby the effective intermediate-frequency bandwidth of a radio receiver can be made exactly that of the passband of a low-pass audio filter, instead of approximately twice that passband as in conventional a-m practice. This technique, in effect, makes possible the design of single-sideband receivers in which audio selectivity is the equivalent of i-f selectivity. As a result, the cost of receivers having a square-sided band-pass response of sufficient sharpness to take full advantage of the saving in bandwidth afforded by single-sideband transmission need not be greater than that of present-day communication receivers. In addition, it is possible to convert existing equipment to take advantage of the new system.

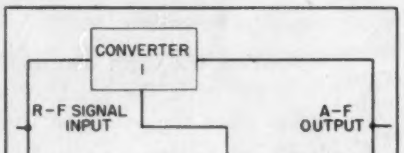


FIG. 1—Block diagram illustrating basic system

Advantages

The circuit to be described offers some advantages in the reception of conventional code signals. All incoming noise or code signals higher, or lower, in frequency than the final beating oscillator can be virtually eliminated from the output. The effective bandwidth of the receiver is thereby halved, since signals are heard on one side of zero beat only. Moreover, it is possible to select the side of zero

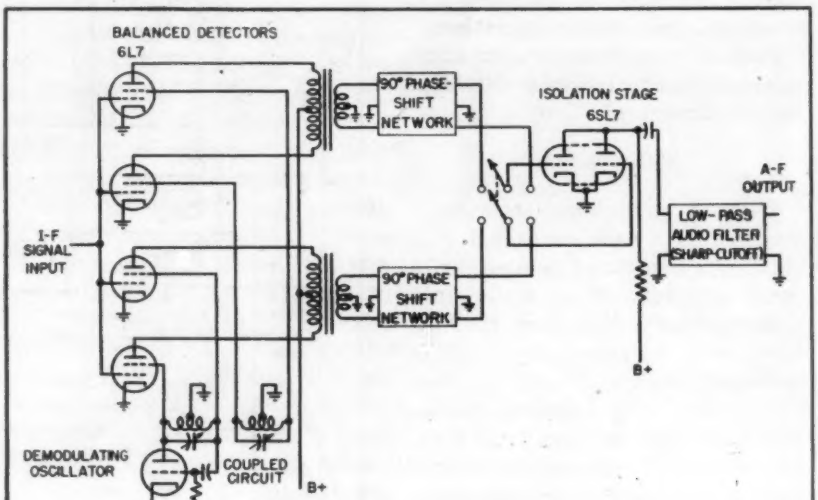
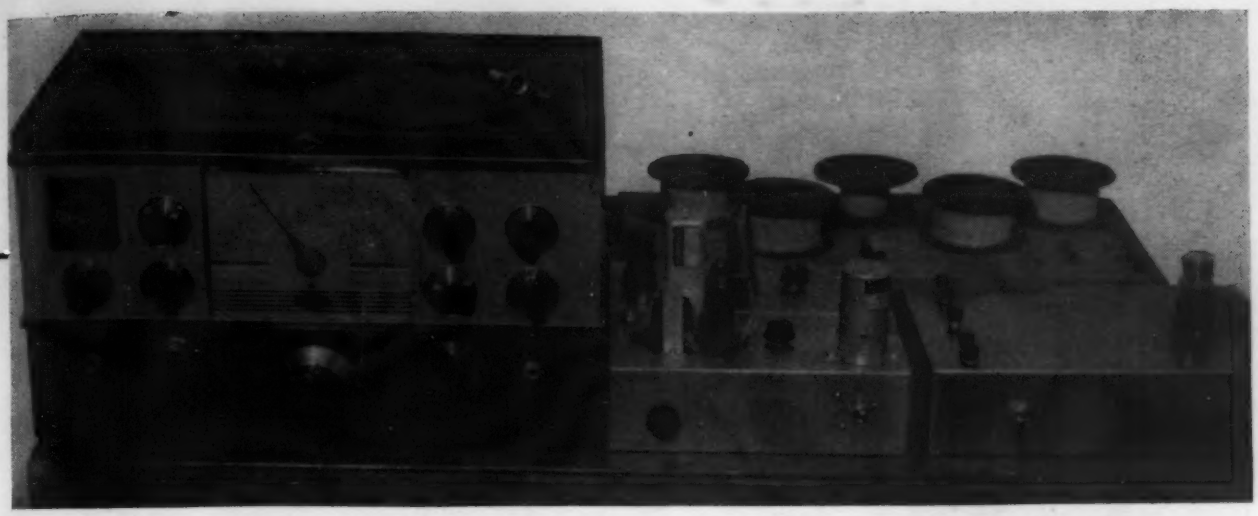


FIG. 2—Simplified schematic of single-sideband detector circuit



Laboratory model of accessory equipment used with a communications receiver for single-sideband reception

beat on which signals are heard simply by throwing a switch. Alternatively, it is possible to listen to signals on the two sides separately and simultaneously. Two operators can listen without mutual interference to two different sets of transmissions coming from the output of a single receiver, one hearing all signals higher in frequency than that of the beating oscillator and the other hearing all signals lower in frequency. In the same way the system may be used to separate multiple single-sideband transmissions; conversations carried by the lower sidebands of a given suppressed carrier appear in one output channel, while those carried by the upper sidebands appear in the other.

Circuit Operation

Operation of the circuit is easily explained. First, it must be remembered that detection is essentially a process of frequency conversion. Signals become intelligible as soon as they are translated from the radio-frequency spectrum down to their correct place in the audio-frequency range.

Frequency conversion can be accomplished by either of two methods that are ordinarily equivalent but which have an important distinction from the standpoint of the present discussion. Basically, it is desired to generate difference frequencies falling in the audio range by combining an incoming radio-frequency signal with a local oscillation. The desired difference frequencies can be generated by superposition of signal and local oscillation and rectification of the resulting envelope, or by modulation of signal by local oscillation (or vice versa) whereby the lower sideband is the desired difference frequency. It is important, in single-sideband detection, to avoid the production of beats between the sidebands themselves or beats between the sidebands and adjacent interfering signals which might produce spurious audio-frequency output. Because this effect may readily take place with the first method as a consequence of the rectification process the second method is to be preferred for the present purpose because the incoming signal which is modulated by the local oscillation can be handled in a class-A amplifier possessing as nearly linear a grid voltage-plate current characteristic as possible.

Let the demodulating oscillator voltage be expressed by $E_1 \sin \omega_1 t$, and let an incoming sinusoidal single-sideband signal be $E_2 \sin \omega_2 t$. The incoming signal is fed simultaneously to two frequency converters. One of the converters is supplied with oscillator voltage and the other receives the same voltage shifted 90 degrees in phase, or $E_1 \cos \omega_1 t$. The output of the first converter is then

$$e = m\, E_1 \sin \omega_1 t\, E_2 \sin \omega_2 t = \frac{m\, E_1\, E_2}{2} \cos (\omega_1 - \omega_2) t - \frac{m\, E_1\, E_2}{2} \cos (\omega_1 + \omega_2) t$$

where m = modulation factor (a constant)

The right-hand portion of the second expression is the upper sideband, in which we have no interest. If $\omega_1 > \omega_2$, the left-hand portion is positive; if $\omega_1 < \omega_2$, it remains positive because $\cos(-\alpha) = \cos \alpha$. The output of the second converter is

$$e = m\, E_1 \cos \omega_1 t\, E_2 \sin \omega_2 t = -\frac{m\, E_1\, E_2}{2} \sin (\omega_1 - \omega_2) t + \frac{m\, E_1\, E_2}{2} \sin (\omega_1 + \omega_2) t$$

If $\omega_1 > \omega_2$, the left-hand portion of the second equation is negative; if $\omega_1 < \omega_2$, it becomes positive, because $\sin(-\alpha) = -\sin \alpha$.

Thus the first converter gives a difference-frequency output whose relative phase may be thought of as not changing as the incoming frequency passes from lower to higher than that of the oscillator. The second converter on the other hand gives an output whose relative phase does change by 180 degrees as zero beat is crossed. Now, by means of a 90-degree wideband phase shifter it is possible to delay the audio output of the second converter until it becomes

$$-\frac{m\, E_1\, E_2}{2} \cos (\omega_1 - \omega_2) t.$$

This voltage, if added to the output of the first converter when $\omega_1 > \omega_2$, will produce cancellation, whereas if $\omega_1 < \omega_2$ direct addition results. Thus, by means of a 90-

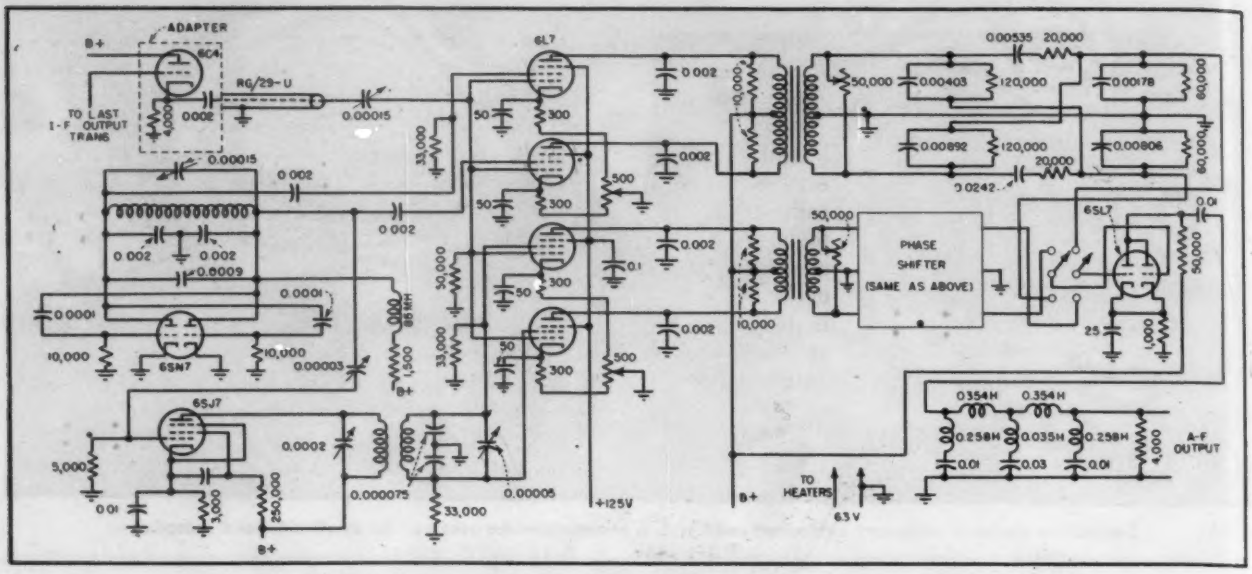


FIG. 3—Complete schematic of single-sideband reception accessory for communications receiver

degree wideband phase-shift network and two detectors fed by radio-frequency voltages in phase quadrature, it is possible to reject signals on one side of the beating oscillator and pass those on the other.

A block diagram of the basic method is shown in Fig. 1.

Practical Application

Balanced detectors are used in the practical circuit in order to reduce the likelihood of demodulating beats between components of the incoming signals, in addition to the beats between this incoming spectrum and the local oscillator. The balanced arrangement is particularly important where strong adjacent-channel interference may be encountered and where detection is done at relatively high signal levels (of the order of tenths of a volt.) Under these conditions curvature of the grid-voltage plate-current characteristic of most vacuum tubes will produce appreciable even-order distortion and even-order sum-and-difference frequencies. These effects result in spurious audio output since they may be produced by two radio frequencies anywhere in the input signal spectrum.

The balanced detector arrangement eliminates even-order distortion but does not affect odd-order distortion and odd-order sum-and-difference frequencies arising from the rate of change of curvature of the grid-voltage plate-current characteristic. However, odd-order distortion may be minimized by using tubes of the remote-cutoff type which are especially designed to have a low rate-of-change of curvature. The balanced detector using remote-cutoff tubes such as the 6L7 makes it possible virtually to dispense with i-f selectivity provided a highly selective audio filter is used, since only those beats between local oscillator and incoming signals which fall within the passband of the audio filter will be heard.

The 90-degree phase shift between the demodulating voltages fed to the injector grids of the pairs of detector tubes in Fig. 2 is conveniently obtained by taking advantage of the quadrature relationship between voltages across two coupled circuits tuned to resonance. For convenience in adjustment, a buffer tube is employed between the oscillator and the coupled circuits in the actual unit, since tuning the coupled circuit would otherwise affect the oscillator frequency.

The two 90-degree audio phase-shift networks shown are identical. While a network of this type produces two output voltages having a phase difference of nearly 90 degrees over a wide range of frequencies, the phase of these output voltages themselves bears no fixed relationship with that of the common input. It is therefore necessary to use two identical networks in order to obtain two voltages between which a 90-degree phase exists, assuming the two separate input channels to be in phase. In practice the phase of the two channels may be arbitrary, and a quadrature relationship is actually used.

Employment of two identical 300 to 3,000-cps networks connected to the outputs of the two balanced detectors also prevents any amplitude unbalance affecting the degree of undesired-signal cancellation arising from the variation in input impedance of each filter with frequency. Variation may affect the overall frequency response, since the 6L7 tubes may be considered as constant-current generators whose output voltage is proportional to the output impedance, but it does not affect the ratio of the outputs of the two detectors and therefore cancellation of the undesired signal. When the primaries of the audio transformers are loaded with resistances low enough to damp out transformer resonances, it is found that the input impedance of the phase-shift networks has a negligible effect on the overall frequency response.

Figure 3 shows the complete schematic diagram of a single-sideband detector which may be added to a standard communications receiver. Connection is made by removing the receiver's second detector tube, plugging in an

adapter, and then plugging the detector tube into the adapter. A 6C4 cathode follower couples i-f output into the single-sideband detector circuit without disturbing normal operation of the receiver except for a slight retuning of the secondary of the last i-f transformer.

Balancing controls for the two detectors are potentiometers in their cathode circuits. The secondary of the i-f transformer connected to the 6SJ7 buffer tube is resistance-loaded in order to broaden the tuning and make the phase setting less critical. Variable resistors shunted across the secondaries of the output transformers provide a convenient means of equalizing the magnitude of the detector outputs. The low-pass filter used in the common output is a home-made *m*-derived affair cutting off at 2,500 cycles per second and designed for a 4000-ohm characteristic impedance.

Circuit Adjustment

Tuning up the circuit is straightforward. The beat-oscillator voltage at the 6L7 grids can be set at 15 volts just as in conventional converter service. Detector balance is determined by turning off the oscillator and removing or disconnecting one pair of 6L7's. A strong steady signal, such as that from a broadcasting station, is tuned in and the balancing resistor of the remaining pair of tubes adjusted for minimum audio output. This process is then repeated with the first pair of tubes. With the correct adjustment the detector should produce a deafening output with the oscillator turned on, whereas there should be no audible output at all with it off.

Adjustment of the radio-frequency phase of the local-oscillator signal at the second balanced detector is easily made. With the secondary of the i-f transformer tuned for maximum voltage at the 6L7 injector grids the phase is approximately correct. This condition can be verified by connecting the horizontal and vertical plates of an oscilloscope to the secondaries of the audio-output transformers. If the amplitude balance is approximately correct a steady a-m signal such as a broadcast station will give a weaker beat note on one side of resonance than on the other. Tuning to the weaker side, the amplitude balance is set for greatest rejection and likewise the radio-frequency phase setting touched up. For any given pitch of beat note the balance may be made complete and the beat eliminated completely by adjustment of phase and amplitude. The procedure is exactly like that of balancing a bridge. However, since the 90-degree networks do not give a perfect 90-degree phase shift as well as a perfect amplitude balance at all frequencies it will be

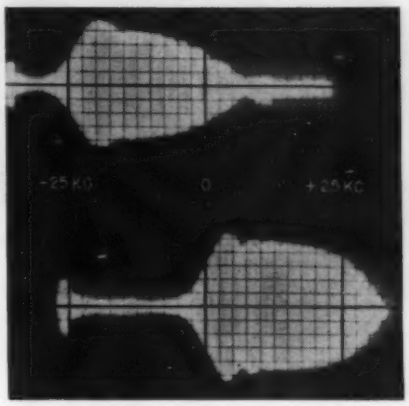


FIG. 4—Oscillograms showing rejection of upper sideband (top) and lower sideband (bottom)

found that the rejection, while perfect at one frequency, is imperfect at others. As a compromise, it is best to adjust for complete cancellation at a frequency in the vicinity of 1,000 or 2,000 cycles, where the ear is most sensitive.

The laboratory model for which the schematic is given could be considerably simplified. Dual triodes or even detector crystals could be substituted for the 6L7 mixers. If mixing is done at low enough levels the balanced connection could probably be dispensed with. The local oscillator could be simplified and the buffer tube eliminated by making the oscillator a pentode tube with electron coupling between the frequency-determining elements and the plate circuit to which the i-f transformer would be connected.

Figure 4 is an attempt to illustrate the properties of the circuit by means of the familiar frequency-modulated oscillator technique. Owing to the presence of the demodulating oscillator there is displayed on the oscilloscope screen a continuously-varying audio beat between the frequency-modulated test oscillator and the steady demodulating oscillator. The audio-frequency waveform has random phase because the two oscillator phases are unrelated, and hence does not remain stationary. The envelope of this waveform is an indication of the overall selectivity curve of the detector circuit. It is not entirely representative because at the oscillator sweep speeds available, transient response effects in the sharp-cutoff audio filter considerably distort the envelope. The patterns show spurious humps and are not as symmetrical as would be the case if the response curve had been plotted with a very slow rate-of-change of sweep-oscillator frequency. Rejection of the undesired signal is illustrated by the oscillograms, the first of which was made with the sideband-selector switch set at one position, and the second at the other. The amount of rejection shown is sufficient to be quite useful in practice. For example, the reduction in receiver thermal noise output is very marked when the 90-degree networks are added and cancellation takes place.

Transmission tests with an experimental single-sideband phone transmitter on the Stanford University campus have verified the rejection ratio observed in the laboratory measurements. It is quite startling to hear a signal drop out when the selector switch is thrown to the position that rejects the sideband being radiated. Another interesting test is to listen in at a busy hour on one of the crowded amateur c-w bands. By throwing the switch, two entirely different sets of incoming signals can be selected at will.

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Acoustic Problems i

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Modern studio constructed in accordance with the principles outlined in the text. A measure of sound control is provided by the randomly spaced curved surfaces

EXPANSION of present studio facilities or construction of new stations enables the radio engineer to utilize many proven techniques in the control of sound. The technical problem to be considered here is that of noise.

Airborne sounds exterior to the plant include those due to thunder, railways, buses, aircraft, streetcars, industrial activities and automobile traffic. Certain of these, such as railways, streetcars and industrial activities, may transmit sound by vibration of the ground to the studio plant. The rental of space in an existing structure requires investigation of the activities of present tenants, and also the restriction placed on future tenants as to their noise-producing activities. Major sources of noise within the building may include printing presses, pumps, industrial machinery, punch presses and the like. Conversely, noise from a broadcast plant can be just as annoying to others, particularly doctors, or dentists, in the conduct of their work.

A survey with a sound-level meter is preferable but if one is not available, some indication of the noise level may be obtained by the use of a portable field amplifier. The magnitude of the noise may be calculated approximately by obtaining the sensitivity of the microphone from the manufacturer.

If the noise is from a source which develops considerable vibration, the solution may not be economically feasible. The location of the studios on the floor directly above or below a bank of large printing presses is such an example. The amount of vibration generated by the presses is of such a magnitude that there is no practical and economic means to reduce it to a satisfactory value. Further, it is not possible to predict accurately the reduction which will be effected because of the many related factors.

Studios have been built in substantially this type of location and, as far as is known, trouble has always ensued—sometimes to the extent of making necessary the installation of a high-pass filter in the program circuit to reduce the noise and compromise the overall quality.

The maximum tolerable noise level in studios is as follows: Sound-level meter on Scale A—less than 25 db above the threshold of hearing, on Scale B—less than 35 db, and on Scale C—less than 45 db. Scale C is substantially flat as regards frequency response and Scales B and A correspond respectively to the loudness intensity curves of the human ear. These curves show that the ear at moderate intensitities is less sensitive at the lower frequencies than at medium and high frequencies. This is fortunate as the lower frequencies are most difficult to control.

Boundary Surfaces

The attenuation of airborne sounds is usually dependent on mass of insulating material rather than other characteristics. The increase in attenuation with mass is at a relatively slow rate as may be seen in Fig. 1. For example, a 6-inch wall (45 pounds per square foot) of solid cinder concrete may be expected to have an average attenuation (128 cycles to 4,096 cycles) of about 48 db and a 12-inch wall (90 pounds per square foot) about 54 db.

Two 6-inch solid cinder concrete walls with an intervening air space of more than 6 inches may be expected to produce an attenuation of about 60 db. Double walls are preferable to single walls, because of the increased sound attenuation over a single wall, the reduction of impact sounds, and the lesser weight for a given degree of sound attenuation.

Partitions should extend from the floor slab to the under portion of the

in Studio Design

Planning a broadcast studio involves considering noise originating both inside and outside the building. Construction of walls, ceiling and floor should attenuate airborne sounds and those due to transmission of vibration

floor slab above. Cinder block walls have appreciable sound-absorbing properties which absorb sound in the intervening space between walls and also are fairly free from pronounced resonances which are manifest as reduced attenuation over a band of frequencies.

The use of two 6-inch solid cinder block partitions (each plastered on the outside) separated by an air space is the minimum that should be provided between adjacent studios. The use of partition block of smaller dimensions, say of 4 inches thickness and hollow instead of solid, permits transmission of more sound than is desirable.

Commercial sound isolation systems are effective in attenuating airborne sounds but experience has shown them to be less effective than is desirable in reducing the transmission of vibration at frequencies of about 100 cycles and lower. There are advantages in their use where weight becomes a factor. Construction details of sound isolation systems for walls, floors, and ceilings are shown respectively in Fig. 2, 3 and 4.

Multiple wall structures of light weight are effective in reducing sound transmission but usually such walls occupy appreciable space, are relatively expensive and require careful supervision of their installation to insure proper performance.

Attention must also be given to the ceiling and floor surfaces to insure the maintenance of the high degree of sound attenuation provided by the partitions. In buildings with stone concrete floor slabs of adequate thickness (4 to 6 inches), adequate isolation from the floor above is usually obtained by the installation of a suspended ceiling if the occupants of the floor above are engaged in relatively quiet activities. Such a ceiling is required for light fixtures, concealing duct work and the like. The ceiling should be supported on resilient mountings and covered by loose rock wool fill, blanket or similar sound-deadening material.

The floor on which the studios are mounted should be also studied as to noise coming from the floor below and additional cinder fill topped by smooth concrete finish added or a sound-isolated floor installed.

Buildings with wooden floors present some problems as to load-bearing capabilities which may require rearrangement of the studio grouping to obtain isolation by separation rather than structural means.

Wall Openings

In dealing with surfaces pierced by windows, doors, and duct work, every precaution must be exercised to maintain the sound isolation provided originally.

Entrance to a studio should be effected through two doors separated by a vestibule which is acoustically treated over as much area as is possible. Experience has shown satisfactory performance with 2½-inch solid wood doors fitted with an automatic bottom closer and gasketed on the head and side, at each end of the vestibule.

In windows of the control booth and public observation booths, the use of double glass of ¼" and ½" thickness respectively, separated as widely as possible, provides sufficient isolation. The isolation is improved to the extent of 6 to 10 db by acoustical treatment of the boundary surfaces between the panes or lights of glass.

Outside windows should be sealed by masonry or treated in the same general manner as control booth windows if retained, to prevent transmission of sound between the studio and outside spaces.

Ventilating Systems

All rotating and reciprocating machinery of air-conditioning and

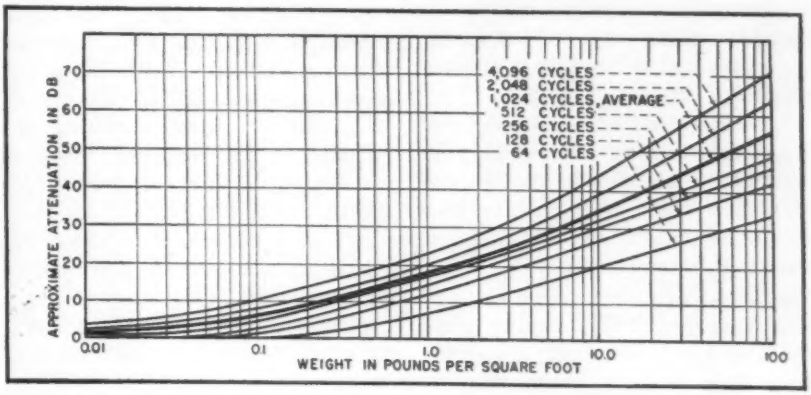

FIG. 1—Sound attenuation in terms of weight of various homogeneous materials. The average curve of loss from 128 to 4,096 cycles is the same as the 1,024-cycle curve

ventilating systems should be mounted on a vibrator-isolated base. Suitable isolation materials or springs include rubber in shear, metallic coil or leaf springs and cork. The performance of practically all these materials is dependent on loading and the material should be deflected as much as possible to obtain a low natural resonant frequency and to provide the greatest amount of isolation. All connections to the equipment should be flexible, and electrical wiring enclosed in flexible armor rather than conduit.

Duct work should be connected to the fan through a canvas collar and the same procedure employed in connecting the duct work to the supply and return outlets. The duct work should be wrapped where it pierces the wall and wrapped within the confines of the studio. A duct of dimensions of 12 × 12 inches or smaller should be lined for a distance of 16 feet between the fan and the first outlet; and between outlets in studio and other spaces. Duct work to listening areas, such as control booths when of this dimension or smaller, should be lined for a distance of at least 8 feet. The lining should bridge partitions which are pierced by several feet on each side of the partition.

In the case of a duct 12 × 48 inches, it should be lined as indicated above and divided at 12-inch intervals or less by absorbing material so that in effect four small ducts in parallel are created.

The supply and return outlets are another source of noise if the air velocity is too high or the duct work is not arranged for a smooth flow of air. Guiding radial vanes should be employed as required which will aid in the distribution of the air in the studio and also result in quieter conditions.

Air velocities which have been found satisfactory are 1,200 feet per minute or less in main duct work; 500 feet per minute or less for supply outlets, and 300 feet per minute at return outlets.

Recessed light fixtures can be arranged to pierce the ceiling construction and the manner of mounting to observe sound precautions is shown in Fig. 5.

There remains the selection of

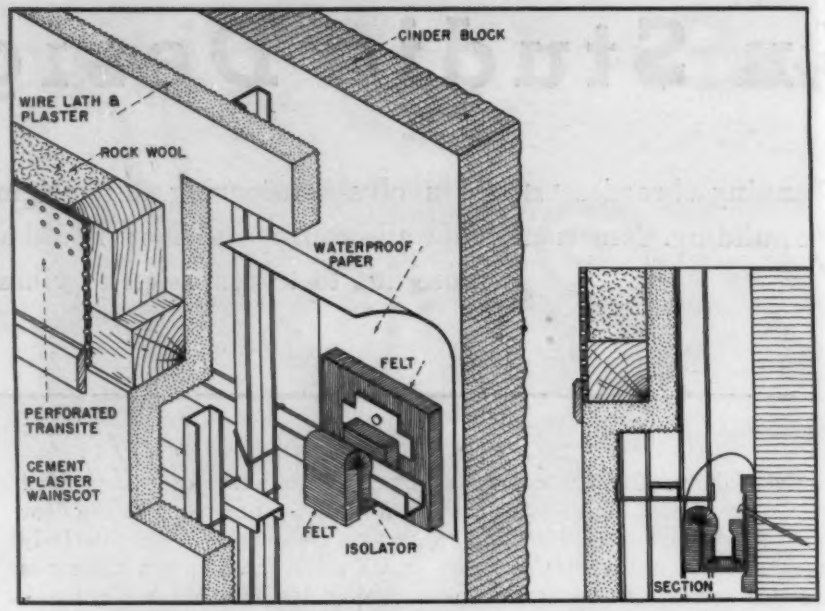

FIG. 2—Construction of a wall for sound isolation between studios

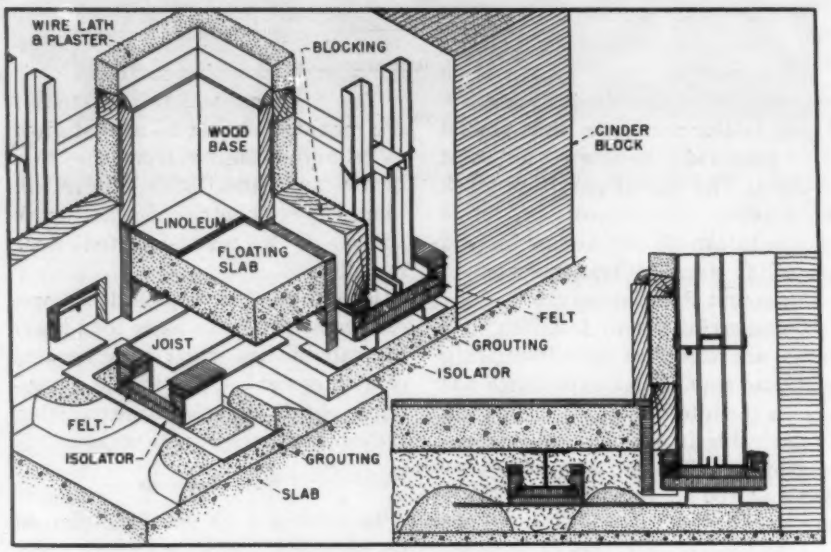

FIG. 3—Typical acoustic treatment for a floor to isolate sound from below

the type and thickness of material and its distribution in conjunction with reflective areas. Acoustical plaster is usually of only moderate absorbing efficiency at medium and high frequencies but the absorption is subject to some variation dependent on job conditions such as the manner of mixture, pressure of the trowel or applicator. Its relatively poor resistance to abuse restricts its use to ceilings, if used at all, in studios.

Draperies and carpets in general have little absorption at the lower frequencies and the absorption increases with the frequency. Draperies, lined and interlined, hung 100-percent full (twice the area of material is required for the area of wall to be covered) and one foot or so from a wall will have very appreciable low-frequency absorption.

Carpeting is useful in seating sections on the walking area of auditorium studios, on the floor of speakers' studios, under a microphone stand to reduce scuffling of feet, and in certain cases to reduce the noise of footsteps.

Acoustical tiles provide fairly high absorption at medium and high frequencies and a lesser degree at low frequencies dependent on the manner in which they are mounted on ceilings or walls. Certain types

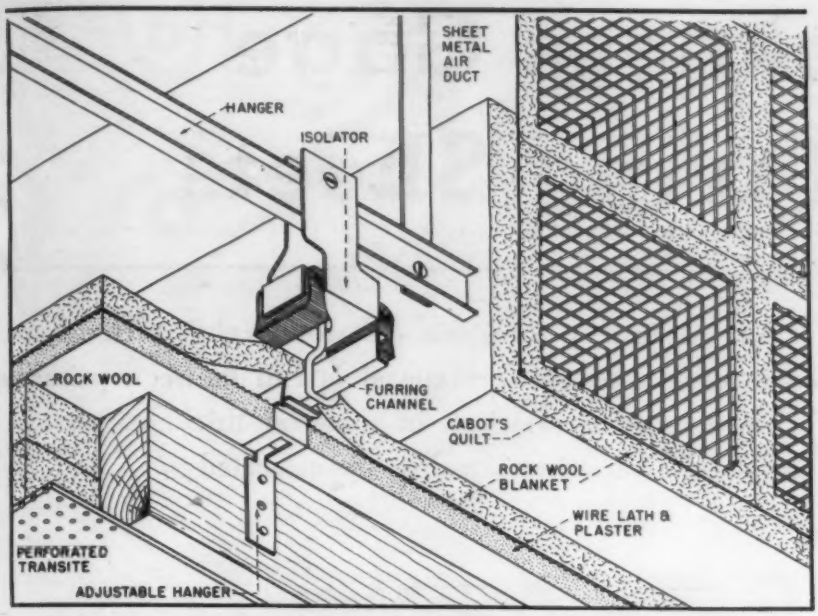

FIG. 4—Mechanical details of a suspended ceiling and acoustically treated air duct

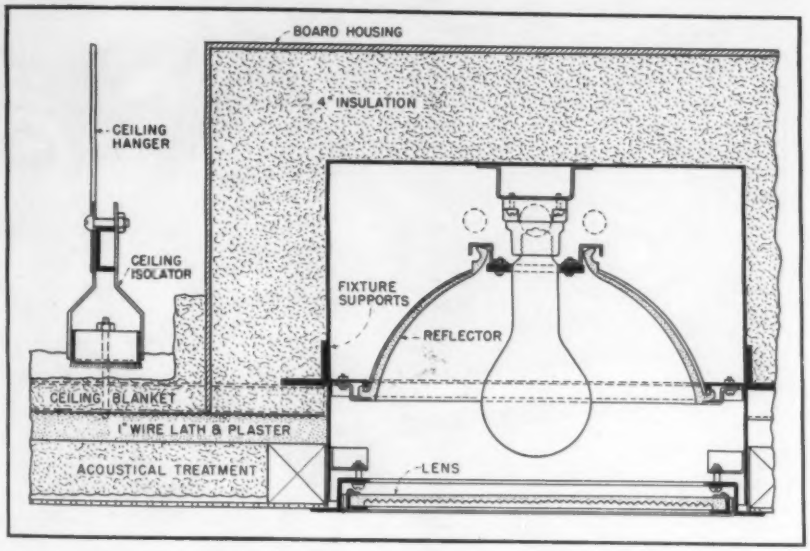

FIG. 5—Detail of acoustical treatment around recessed lighting fixtures

which are homogeneous and rely on the porosity of the material for absorption tend to be fragile and subject to discoloration due to breathing, discoloration due to temperature and pressure differentials which tend to entrap the dirt on surfaces due to the passage of air through the tile near the exposed surface. Acoustical plaster is also subject to this effect.

Porous tiles, like acoustical plaster, may be subjected to indiscriminate painting when redecoration is necessary and even careful painting invariably substantially reduces the absorbing efficiency. Typical cases have shown a reduction from 50 to 60 percent down to 20 to 30 percent.

Membrane-covered absorbing materials are those in which the perforated membrane whether it be metal, asbestos board, or hardboard, serves as an acoustically transparent covering of the absorbing material up to about 4,000 cycles after which the covering becomes increasingly reflective. These coverings are fairly abuse-resisting and capable of painting several times without adverse effects on the absorbing efficiency.

The control of absorption at the low frequencies can be accomplished by an increase in thickness of one or more of the materials selected, the furring or mounting of the treatment at some distance from the wall or the use of large areas of generally reflective curved surfaces which have appreciable absorption at low and medium frequencies and almost none at high frequencies.

Studio Furnishings

Speakers' studios intended to resemble a living room should employ a carpeted floor with lining and an untreated ceiling. The walls may be treated with an appropriate area of commercial acoustical treatment or heavy draperies. Since these rooms may be small and used mostly for speech, particular attention should be given to provide adequate low-frequency absorption to avoid boomy and unnatural speech sounds. Where draperies are employed it may be necessary to mount two inches or more of rock wool blanket or similar material behind the drapery to raise the low-frequency absorption.

General purpose studios should have a floor covering of linoleum or similar sound-reflective material. The wainscot or chair rail should be of abuse-resisting material such as cement plaster about 3 feet 6 inches or 4 feet high.

There is a variety of arrangements of wall and ceiling treatments and only generalized suggestions can be made. The peripheral area of the ceiling may be untreated so long as the distance from the side walls is less than 3 to 4 feet. If this distance becomes larger the area should be convexly curved, splayed or a band of acoustical treatment provided.

Large areas of reflective surfaces parallel to the floor centrally located must be avoided, because of the danger of persistent vertical reflection in the microphone field. The wall treatment should be arranged in some decorative pattern of curved or serrated reflective surfaces alternated with absorbing areas.

The importance of proper planning in matters of sound control cannot be too greatly emphasized. Many problems may be anticipated and the solution effected before the trouble develops which will later prove to be more economical, practical and convenient.

Thickness Gage for Moving Sheets

Glass and other nonmagnetic sheets ranging in thickness from one-eighth inch to one inch can be continuously gaged to close tolerances. Material is run between primary and secondary of a measuring transformer. Variations in material thickness change coupling, upset bridge balance and are directly indicated

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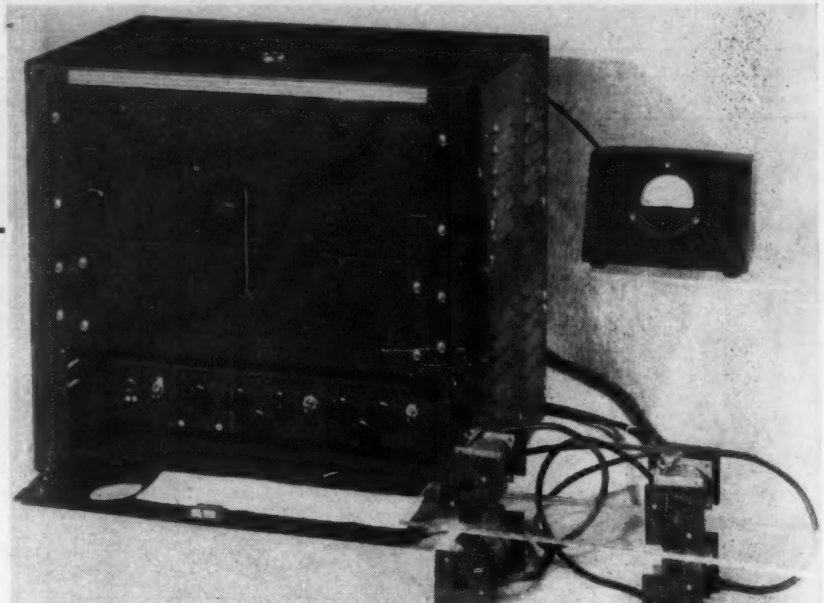


Electronic thickness gage. The indicating meter may be seen at the upper right. Standard and measuring heads, shown without their mounting fixtures and roller wheels, are at the lower right

AN ELECTRONIC GAGE has been designed to fill the need for an instrument that will continuously measure the thickness of glass or any other nonmagnetic material.

The gage consists of standard and measuring heads, a source of power for energizing the two sets of heads which are continuously balanced against each other in a bridge arrangement, a phase-inversion system, an amplifier, and an indicator. The instrument may be used in conjunction with a high-speed recorder when permanent records are desired.

Standard and Measuring Heads

The standard and measuring heads comprise the primary and secondary windings of special audio-frequency transformers. They are energized by a stabilized oscillator built into the system. Changes in the spacing between a primary and secondary vary the degree of coupling. The relationship between change of spacing and change in secondary voltage is approximately linear for base separations ranging from $\frac{1}{8}$ inch to 1 inch. Gage sensitivity is sufficient to give full-scale meter readings with as little as plus or minus 0.0005 inch from the mean thickness. The usable range of the instrument is approximately 0.001 inch to more than 1 inch.

In order to provide a reading representing deviation from standard thickness rather than total thickness the secondary voltage of the measuring head is displaced 180 degrees and balanced against the secondary voltage of the standard head. Standard head spacing is set by inserting a standard-thickness flat. This form of pickup makes the instrument suitable for measuring any nonmagnetic material.

Balance is established by adjusting front-panel controls with identical standard flats in both heads. The measuring head is then placed on the work. So long as the work remains on thickness, the voltages from the measuring head and the standard head balance to zero. If the work goes undersize, voltage from the measuring head predominates and the resulting signal reduces the final meter reading below midscale or zero deviation position. If the work goes oversize, the voltage from the standard head predominates and the resulting signal

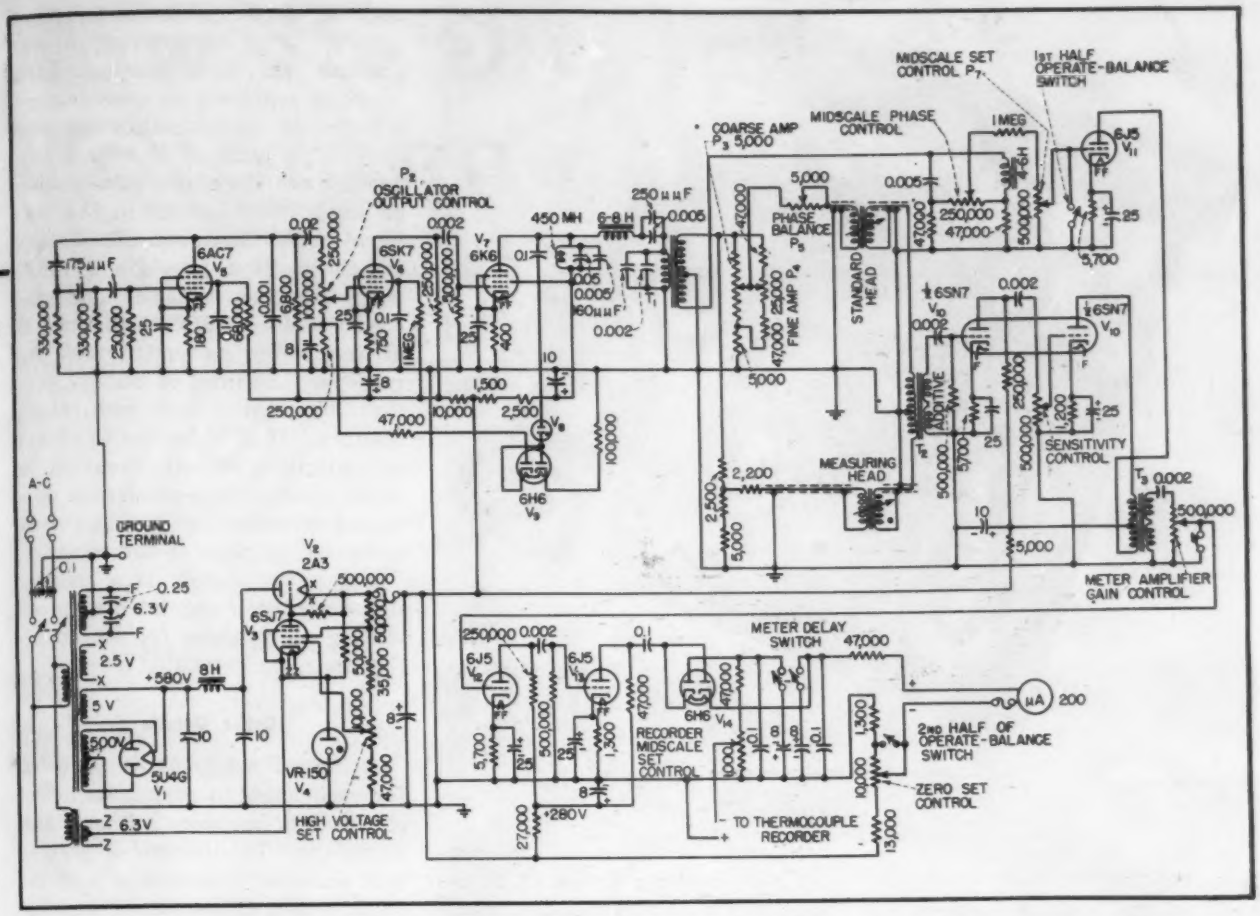


FIG. 1—Circuit of the gage, including voltage-regulated power supply. A high-speed recorder can be used externally

increases the final meter reading above midscale.

Oscillator and Amplifier

The built-in oscillator is a phase-shift type consisting of a three-mesh resistance-capacitance phase-shifting network, shown in Fig. 1, and produces a sine-wave voltage of 1,000 cps. Gain of the oscillator stage V_6 is held to a value which is just sufficient to maintain oscillation. Almost pure sine-wave output is obtained, along with good frequency stability.

The amplifier stage V_6, following the oscillator, uses automatic gain control to provide a signal voltage of constant amplitude. Even though voltage regulation is employed for the plates and screens of all tubes, large changes in heater voltage would otherwise result in some change in oscillator output amplitude.

Automatic gain control is obtained by supplying V_6 with a negative grid bias proportional to the signal amplitude in the plate circuit of amplifier V_7. The avc circuit consists of V_8, a ½-watt neon bulb used as a voltage regulator and V_9, a duodiode connected as a full-wave rectifier. Full-wave rectification of the signal voltage at the plate of V_7 is used to provide a symmetrical and constant load for V_7. Negative alternations are used to supply automatic bias for V_6.

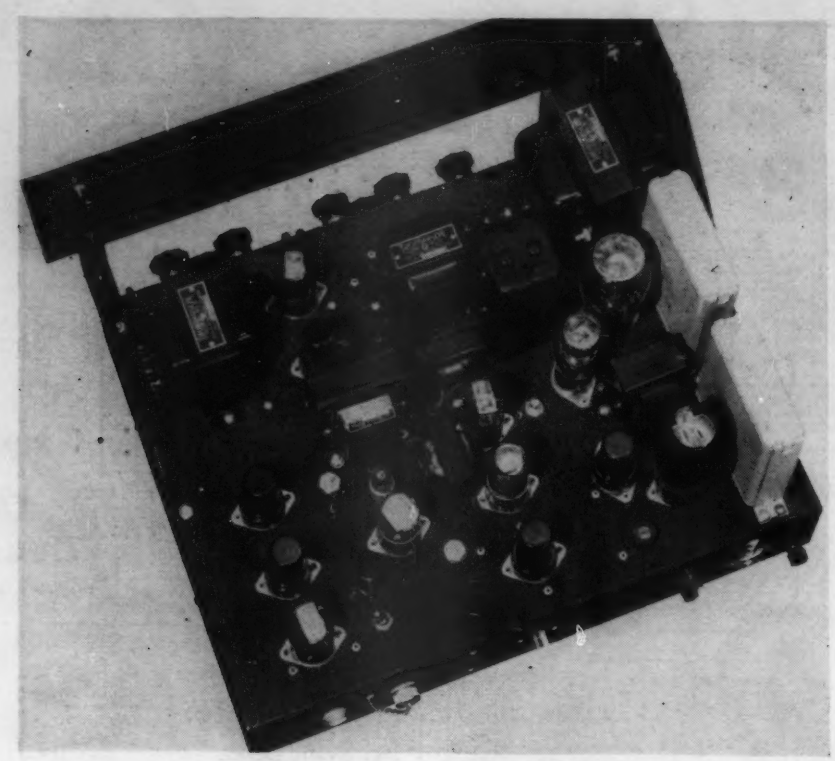
The oscillator output control, P_2, is adjusted so the ionization of the neon bulb V_8 ceases when the line voltage is reduced to approximately 95 volts. When so adjusted, the amplitude of the signal at the plate of V_7 will remain substantially constant for line voltage variations down to approximately 95 volts and up to 130 volts.

Bridge Circuits

Output of V_7 is coupled to the heads and V_{12} through T_1. The plate circuit of V_7 contains three resonant circuits, each tuned to 1,000 cps, for preventing the transmission of harmonics.

The two heads are connected to one side of transformer T_1 secondary through their respective voltage-divider networks. The measuring head is supplied with a fixed-amplitude voltage, while the voltage applied to the standard head, is adjustable in amplitude and phase for bridge alignment and calibration. Amplitude adjustment of signal voltage applied to the standard head is obtained by means of two controls, P_3 and P_4, for coarse and fine amplitude adjustment.

Phase adjustment of the input voltage to the standard head is provided by a simple L-R circuit. The inductance of the head and P_5, the phase-balance control, serve as the elements in the phase-shift circuit. Phase adjustment of voltage to one of the heads is necessary to compensate for small circuit differences in the two branches. The phase balance is adjusted until the secondary voltage of transformer



Chassis of the thickness gage

T_2 is zero when the heads have the same spacing.

When the spacing between the primary and secondary of the measuring head is changed, an unbalance exists in the input of transformer T_2, resulting in a secondary voltage which is amplified by both sections of V_{10}, the output of which is applied to one-half of the primary of transformer T_3. The other half of the primary is supplied with a voltage at the same frequency from amplifier V_{11}. Input for V_{11} is supplied from the same transformer, T_1, that supplies voltage to the measuring heads. The input is supplied through an L-C-R phase-shifting network. Adjustment of phase of the input voltage to V_{11} is necessary so that the input voltage to each half of transformer T_3 is exactly in, or 180-degrees out of, phase. Any voltage appearing in the secondary of T_3 will therefore result from the sum or difference, depending upon phase, of the amplitude of the two primary voltages.

Indicator and Power Supply

Under normal conditions P_7, the midscale set control, is adjusted to give half-scale reading of the indicating meter when the heads are in a balanced condition. If measuring-head spacing increases it results in a voltage, applied to transformer T_3, of such polarity as to add to the voltage supplied by V_{11}. This results in an increase in secondary voltage and, hence, in higher meter reading. If measuring-head spacing decreases, output from V_{10} results. However, under these conditions, the voltage supplied to transformer T_3, from V_{10}, is now 180-degrees out of phase with the voltage supplied the transformer from V_{11}, resulting in a decrease of secondary voltage; hence a reduction in meter reading.

Output of transformer T_3 is applied to a conventional two-stage voltage amplifier consisting of V_{12} and V_{13}, which drives V_{14}, consisting of two half-wave rectifiers. These rectifiers are series connected so that they conduct on alternate half cycles, but carry the same average current at all times. This current is drawn through the indicating meter and returned to ground through a potentiometer across which is obtained the voltage output for a high speed recorder.

The meter rectifier circuit is provided with a long and a short-time constant R-C filter, either of which may be selected by the meter delay switch. With this switch in one position, the meter and recorder readings represent an average over a period of approximately one second. This position is desirable to average out the effects of vibration or small irregularities in the material being measured. The other switch position provides a minimum response time of one-hundredth of a second. Both the inertia of the meter movement and the response-time limit of the eye prevent observation of such rapid changes. If it is desired to obtain an indication of roll vibration or ripple down to one-hundredth of a second variations, an oscilloscope is connected in place of the recorder.

The power supply is a conventional electronic-regulated type obtaining all voltages for its operation from the regulated side.

Other Details

A hinged mounting is provided for each head, to permit variation of spacing between primary and secondary. This is rigid enough so that there is no lateral or angular displacement of secondary with respect to primary. The mounting is spring-loaded to press wheels supporting the two halves of the head against the work. These wheels may be of nonmagnetic metal, or they may be faced with live rubber, so long as the spring loading remains constant for the balance and working positions and does not change appreciably with temperature. The mounting is insulated from the core of the head by plastic, fiber, or hard-rubber washers and is electrically grounded to the supporting machine or to the ground of the electrical power system.

For both balancing and operating positions the heads are placed at least one foot, and preferably two feet away from any iron or steel. Proper pairing of the heads in the mounting is essential. The measuring head and the standard head are located about two feet apart to prevent intercoupling, but are close enough together to experience approximately the same ambient temperature variations.

The main unit may be mounted in any convenient position.

Low-Impedance Reactances for VHF

Flat-plate transmission lines make convenient low impedances at vhf. Such reactances are mechanically large enough even at 1,000 mc to be readily fabricated. Design requirements are developed, and applications to an amplifier and to a matching section are described

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TRANSMISSION LINE SECTIONS are used in very-high-frequency circuits in the same way that lumped reactances are used at lower frequencies. Although open and coaxial lines are frequently employed, flat-plate lines can conveniently be used in both balanced and unbalanced circuits, especially in the region from 300 to 1,000 megacycles. To illustrate the utility of this type of transmission line, design considerations of several circuits using it are described here.

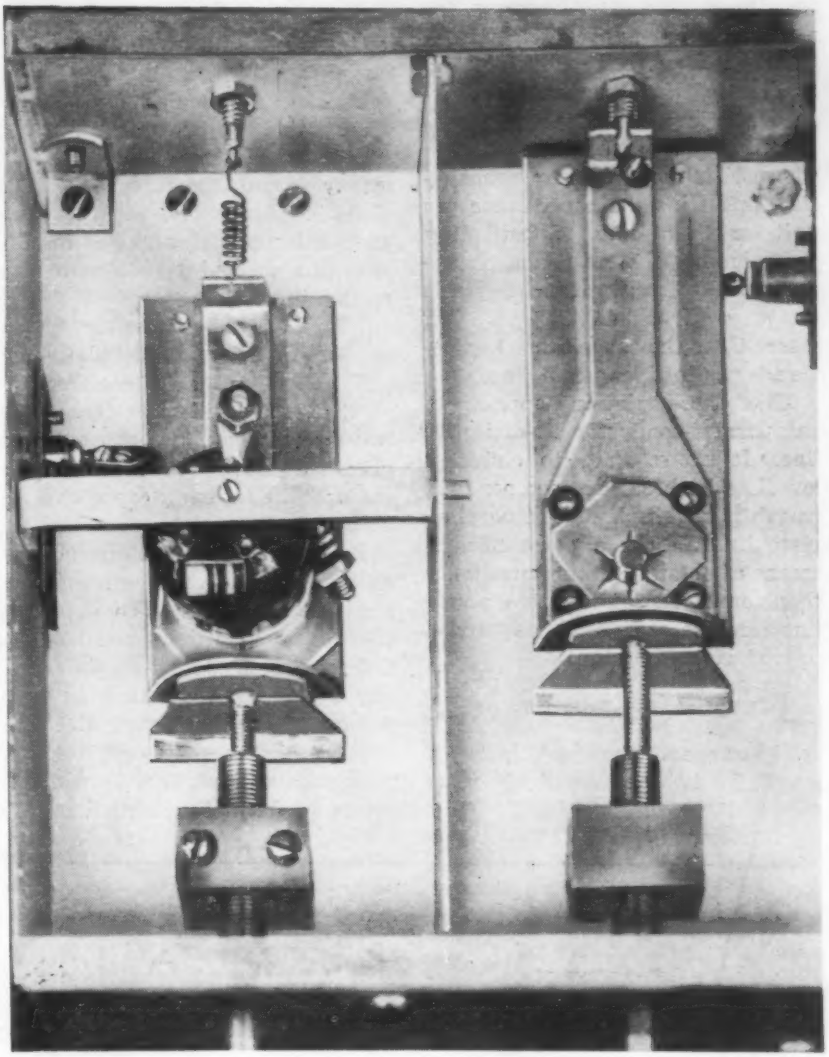
Transmission Line Parameters

At the high frequencies, sections of open or short circuited transmission lines are used as circuit elements in place of lumped reactances because of their negligible losses compared to other circuit elements (input conductance of tubes, antenna radiation resistance, and such). The losses are kept small by using line sections longer than 0.1 wavelength and with spacings between conductors and other dimensions small enough compared to a wavelength so that simple current distributions are maintained.

Reactance of a short-circuited transmission line is

$$X_{sc} = Z_o \tan (2\pi l/\lambda)$$

where l is electrical length of the line, λ is wavelength of the current involved in the same units of length as l, and Z_o is characteristic impedance of the line in ohms. The term $(2\pi l/\lambda)$ is the electrical length in



Two-stage amplifier for 600 mc uses flat-plate lines. One stage is built upside down with respect to the other for simplicity. Consequently this one view shows, in effect, construction of input (left) and output (right) circuits

radians of the transmission line.

For lines such as are considered here, using air dielectric, and with negligible lumped capacitance introduced by mechanical supports, the wavelength is practically the free-space wavelength; the electrical length and the mechanical length of the line are equal.

The above relation shows that, if a low value of reactance is desired for a circuit element, either the line section must have a low Z_o or it must be very short. If the line section is not to be too short; for example, at least 0.1 wavelength long, there is a maximum.

With conventional round-conductor open lines it is difficult to obtain a low enough characteristic impedance to be able to use a reasonably long section of line and still produce the low reactance required for circuit elements. However, for a transmission line with a parallel return and perfect conductors, regardless of their shapes, the characteristic impedance is

$$Z_o = V_o/C_o$$

where V_o is the velocity of propagation, and C_o is the capacitance per unit length of line. Substituting the value of V_o for air, and changing units of length to inches yields

$$Z_o = 84.7/C_o'$$

where C_o' is the capacitance in picofarads per inch length of line.

This last relation applies to any parallel-conductor air-dielectric line. It shows that, to obtain a low Z_o, a high capacitance per unit length is required. A flat parallel-plate line affords a more efficient means of obtaining this capacitance than round rods, and therefore such lines are the basis of this approach to vhf circuit design.

Designing Flat-Plate Circuits

The capacitance per inch of length for two parallel plates in air

$$C_o' = 0.225\ (W/D)$$

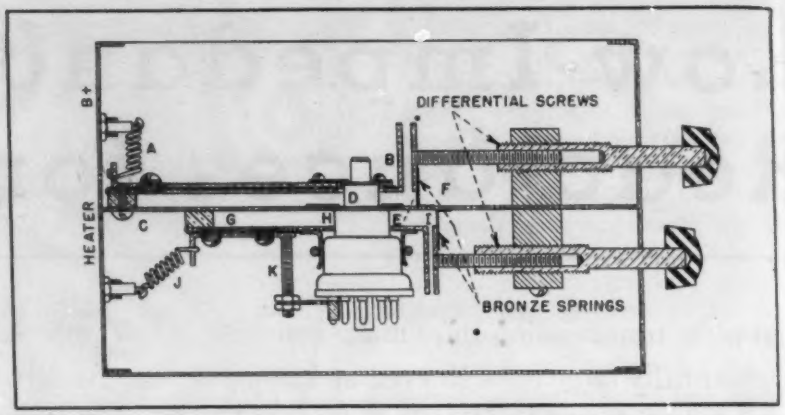


FIG. 2—Cross section of amplifier shows mechanical simplicity of flat-plate construction

where W is width of the plates in inches, D is spacing between the plates in inches, and C_o' is in picofarads. The characteristic impedance in ohms of a parallel-plate line is thus

$$Z_o = 377(D/W)$$

neglecting fringe effects. If the width and length of the plates are large compared to their spacing, fringing can be neglected. Because there would be little object in using flat plates unless they were to be closely spaced, the foregoing equation is reasonably accurate for practical applications. The impedance of a shorted parallel-plate line section is thus

$$X_{sc} = 377(D/W)\tan(2\pi l/\lambda)$$

and of an open parallel-plate line

$$X_{oc} = -377(D/W)\cot(2\pi l/\lambda)$$

so that, for a line less than 0.25-wavelength long, the shorted line gives an inductive reactance and the open line gives a capacitive reactance.

Beyond these basic design requirements there are certain practical considerations. To illustrate these practicalities, consider a 600-mc grounded-grid amplifier using a planar triode, such as in a receiver preamplifier. Although these tubes are designed for use with coaxial lines, they lend themselves to flatline construction.

The basic r-f circuit of such an amplifier, with the plate and heater power feeds omitted, is shown in Fig. 1A. Two resonant circuits are required. The inductive element of each resonant circuit is to consist of a section of shorted flat-plate transmission line enough less than 0.25-wavelength long to present an inductive reactance equal to the capacitive reactance of the tube capacitance.

The plate-grid resonant line is designed as follows: The grid-plate capacitance of the tube is 1.4 pf. It is tentatively assumed that an added variable tuning capacitance of about the same value will be used for adjustment of the resonant frequency of the circuit. The total capacitance is then 2.8 pf. At 600 mc this capacitance has a reactance of 95 ohms.

Primarily because of mechanical considerations involving the diameter of the vacuum tube and the spacing between plates and grid discs, a line having a spacing of 0.2 inch and a width of 1.5 inches is chosen for initial consideration. These dimensions give the line a characteristic impedance of 50 ohms. The wavelength in inches is

$$\lambda = 11{,}800/f$$

where f is frequency in megacycles. For 600 mc, λ is 19.7 inches, or a quarter wavelength is 4.93 inches. Use of the previous equation for X_{sc} shows that the length of line to give 95 ohms is slightly less than 3.5 inches, or about 0.2 wavelength.

A suitable length of line has been determined, but no consideration has been given to the feeding of d-c to the plate connection. It is advantageous to have the line plate

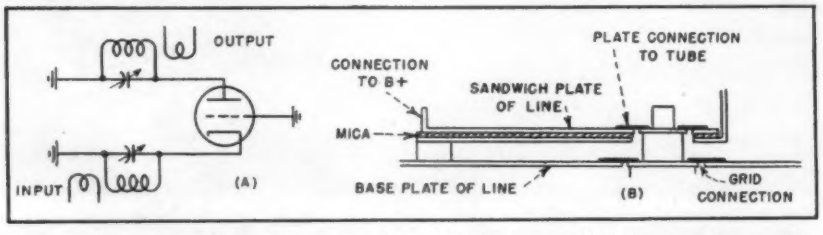


FIG. 1—Basic grounded-grid tuned amplifier (A) for very high frequencies can be made using flat plates (B) one leg of which is built as a sandwich to provide d-c feed

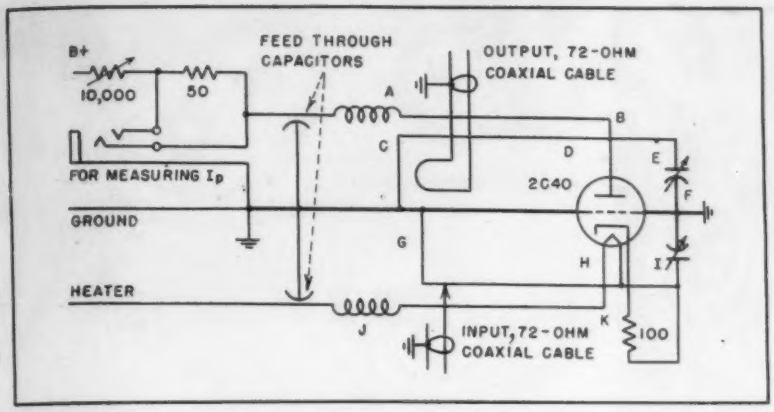


FIG. 3—Points on this schematic diagram are labeled by letters in accordance with Fig. 2

solidly grounded to the main ground plate of the amplifier. A construction that achieves this goal is shown in Fig. 1B. A sandwich type of line is used in which the plate line consists of the main plate which is grounded, and an auxiliary plate which is bonded to the other plate insofar as r-f is concerned but is insulated for d-c by being separated from the main plate by a thin strip of mica.

Tuning of this system is relatively critical and it is necessary to provide a fine tuning arrangement for the variable capacitor at the end of the line, such as a differential screw shown in Fig. 2. As the knob is turned, the inner shaft moves in opposition to the outer shaft so that the resultant movement of the capacitor plate is the difference of the two axial motions.

Numerically, if there are T_1 turns per inch on the outer shaft and T_2 turns per inch on the inner one, the capacitor plate will move as if driven by a simple screw having T_3 turns per inch where

$$T_3 = T_1T_2/(T_2 - T_1)$$

so that, even with coarse threads for T_1 and T_2, the capacitor is driven with a fine motion. For example, if T_1 and T_2 are 24 and 28 turns per inch, respectively, T_3 is 168 turns per inch.

A flat spring is soldered between the movable capacitor plate and the base plate to serve three purposes. (1) It prevents the inner screw from rotating. (2) It takes up backlash in the differential screw so that precision parts are unnecessary. (3) It provides a low-impedance r-f path to the movable plate.

Size of the capacitor plate that is required for this tuning can be computed from the relation for parallel plate capacitors

$$C = 0.225(A/D)$$

where C is capacitance in picofarads, A is area of one plate in square inches, and D is spacing between plates in inches. The area of the plates should be chosen to given a reasonable spacing.

The cathode-grid line can be designed similarly. By operating with one side of the heater grounded and by mounting the cathode-bias resistor directly on the tube base, the bypass capacitor for this resistor being inside the tube, only a single-layer sandwich plate is required. A multiple layer sandwich could be used to allow using an ungrounded heater or measuring cathode current. In constructing an amplifier using the 2C40, the tube is mounted through a large base plate to which the grid is grounded. On each side of the base are mounted the smaller flat plates that form the other halves of each line, as shown in Fig 2. Figure 3 shows the circuit. Coupling to the plate line is provided by an adjustable loop at the edge of the line. Input coupling to the cathode line is obtained by a sliding clip on the edge of the line.

Two stages of preamplification were built using this amplifier design. They satisfactorily replaced a more complicated coaxial-cavity amplifier. The noise factor of the flat-line preamplifier was 9.7 db, the gain of the two stages between 72-ohm input and 72-ohm output was 28 db, and the bandwidth between half-power points with both stages tuned to the same center frequency was 1.67 mc. Wider bandwidth with some loss in gain could be obtained by slight staggering of the tuning.

Other Applications

While the use of flat-plate lines at very high frequencies has been emphasized, this type of line has applications at lower frequencies where low impedances are necessary. For example, it was necessary to match a 17-ohm generator output to a 250-ohm load at 100 mc. A quarter-wavelength matching section was to be used. The characteristic impedance of such a section must be the geometric mean between the two impedances involved, or

$$Z_{OM} = (Z_{OG}Z_{OL})^{\frac{1}{2}}$$

where Z_{OM} is the characteristic impedance of the matching section, Z_{OG} is the impedance of the generator, and Z_{OL} is the impedance of the load. In this case the matching section should have a characteristic impedance of 65 ohms. It can be constructed easily with flat plates 1-inch wide, spaced 0.173-inch, and 29.5-inches long. If the spacing of the line is maintained by insulating washers, they should be as small as possible in order to minimize lumped capacitances.

An incidental advantage of the flat-plate line is its power-handling ability. For the same characteristic impedance, the spacing of a flat-plate line, having plates of the same width as the diameter of the elements of a comparable parallel-wire line, is greater. Hence the flat-plate line will withstand higher voltages without flashover. This is an important consideration in lines for transmitting high power or for sections used as tuning elements in high-voltage circuits.

It should also be noted that, particularly for transmitting r-f power, a flat-plate line can be made of a center plate and a plate on each side, in which case the characteristic impedance will be half that given previously. To increase rigidity, or for some other reason, the line can be made from angle metal. The plate-type line can thus be considered, and used, as an intermediate form between the conventional open-wire line and that of the coaxial line.

Colinear array installed on roof of McGraw-Hill Building for long-distance tests of citizens band coverage

Six-element array installed for coverage tests using receiving locations in New Jersey and Long Island

ANTENNAS for

Antenna gain, readily obtained in small structures at 460-470 mc, is particularly important for the citizens service because of transmitter power limitations. Designs for broadcast and point-to-point service are presented as part of ELECTRONICS' development program

THE DESIGN of transmitting and receiving antennas for the citizens radio service is a matter deserving more attention than is usually paid to this subject in the development of communications equipment. This is true because the transmitter power obtainable from conventional tubes as well as the receiver sensitivity, are low in the 460 to 470-mc band.

Antennas of high gain can be constructed of such small size as to be useful on mobile, as well as fixed, stations. Only in the man-portable equipment is a high-gain antenna apt to prove unwieldy and even then it is possible to use high-gain antennas at certain fixed locations where set is most often operated.

The initial testing of the Electronics transmitter was carried out with a very simple antenna, a quarter-wave rod against a ground plane. The antenna itself is a ½-inch brass rod, 6 inches long and mounted vertically in the center of a 12-by-12 inch solid brass plate. The rod is supported in a polystyrene bushing within a standard male fitting for RG-8/U cable. The brass plate is supported with a half-inch brass post at each corner, each

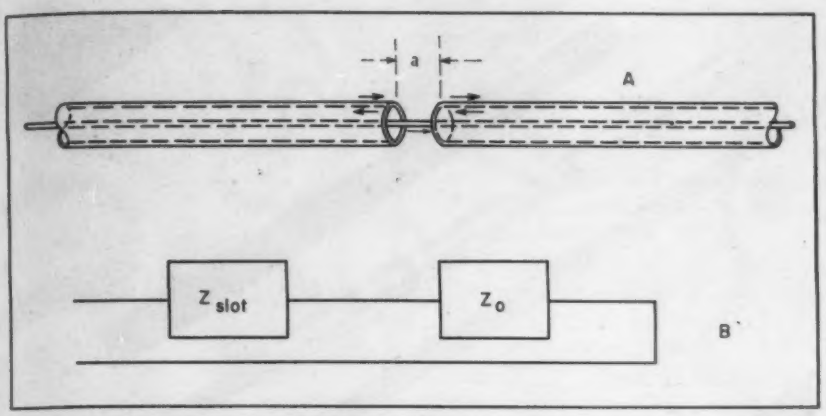


FIG. 1—Slot in coaxial line (A) introduces impedance in series with characteristic impedance (B)

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Part III of a series

Citizens Radio

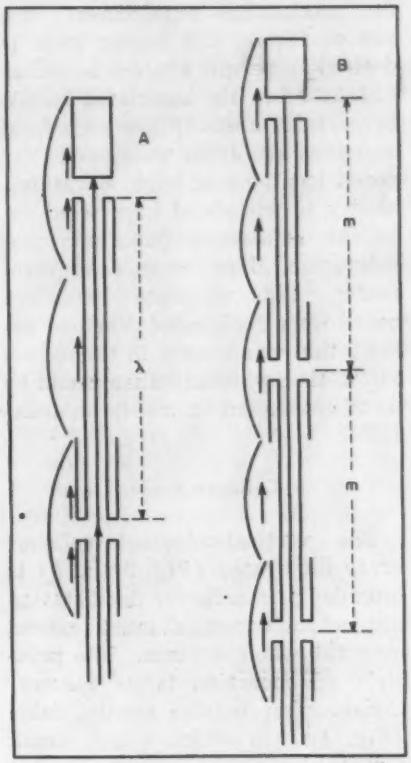


FIG. 2—Three in-phase halfwave radiating elements (A) and five elements (B)

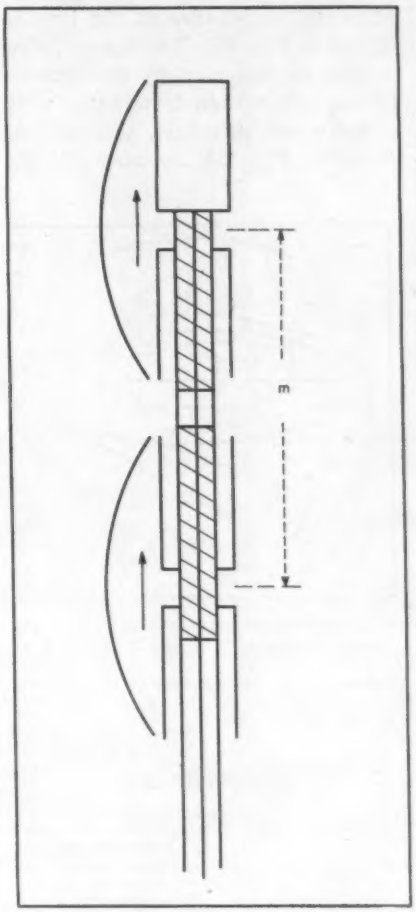


FIG. 3—Internal dielectric slugs preserve electrical spacing at full wavelength

three inches long and fitted with three-inch suction cups so it can easily be attached to the roof of a car. However, actual experience has shown that it is desirable to have more gain in the antenna system.

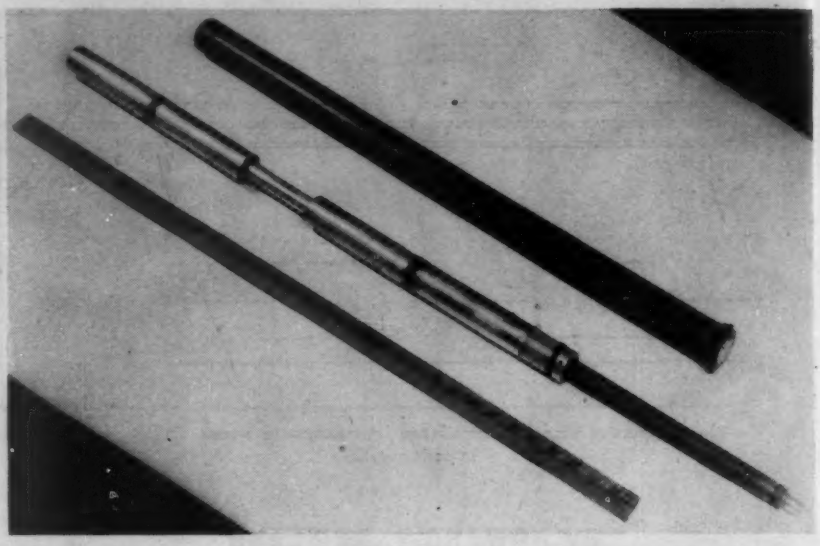
When ELECTRONICS' citizens radio project was announced last November, the writer and his associates became interested in the problem of antennas for this service and offered to assist in the project. As a result two types of antennas were constructed and supplied to the editors for use, with equipment previously described,[1, 2, 3] in field tests of the system. The first antenna, a colinear array giving 360-degree coverage, was adapted from designs previously produced under military auspices. The second, a six-element array for point-to-point service was specially designed for the ELECTRONICS project.

Design Requirements

In view of the wavelength employed and the power limitations of the equipment, the following requirements were set up: The antenna should concentrate the radiated power on the horizon and should direct power only in the desired direction or directions of coverage. The standing-wave ratio should be kept to a minimum to avoid power loss and to assist in stabilizing the tuned circuits. For mobile use the antenna should be as light as possible, weatherproof, and able to withstand vibration and shock associated with vehicles moving over broken terrain.

For fixed-station use the forego-

ing mechanical requirements are not so severe, but higher gain is desired to permit simpler antennas to be used in the associated mobile or portable units. Since such fixed antennas are often mounted in exposed locations at high elevations, ability to withstand high wind velocities is also an important consideration. Based on these requirements, the antennas described below were designated. Vertical polarization was chosen in the expectation that whip antennas would be most convenient in mobile installations.



Internal view of two-section colinear array for broadcast service. A cover of fiberglass tubing protects the array from the weather

Colinear Array

The vertical-polarized colinear array illustrated (Fig. 3 and 5) is intended primarily for fixed station use when coverage must extend over the whole horizon. The principle of operation is as follows: Consider an infinite coaxial cable (Fig. 1A) in which a slot, small compared with the wavelength, has been cut. The slot presents an impedance in series with the characteristic impedance of the line as shown in Fig. 1B. The current flow is then as indicated by the arrows. If the line is then terminated with a halfwave skin-back antenna as shown in Fig. 2A, we may slot the line one wavelength back from the termination and employ phase-reversing skirts to produce the direction of current flow shown by the arrows. This is, in effect, three stacked dipoles in line, fed in phase, producing a concentration of radiated power at right angles to the array. A second slot may be added as in Fig. 2B to add two additional in-phase radiating elements, producing a higher concentration of energy.

In practice it has been found that the spacing m between the slots (Figs. 2 and 3) should be 0.7 wavelength to keep the side lobes 15 to 20 db below the main lobe. To assure a full electrical wavelength within the structure, as required to produce the in-phase condition, the line is partially filled with polystyrene dielectric, as shown in Fig 3.

The measured vertical coverage diagram at 465 mc of the two-section array is shown in Fig. 4, together with computed diagrams for an array having three sections (Fig. 2B) and four sections, all compared with a half-wave dipole. The corresponding power gains, relative to the dipole, the 1.9 for the two-section, 3.2 for a three-section, 4.4 for a four-section and 5.3 for the five-section array. The standing wave ratio in voltage for the two-section antenna is from 1.2 to 1.0 over the band from 460 to 470 mc. The azimuth pattern of the array is circular if the array is mounted well in the clear.

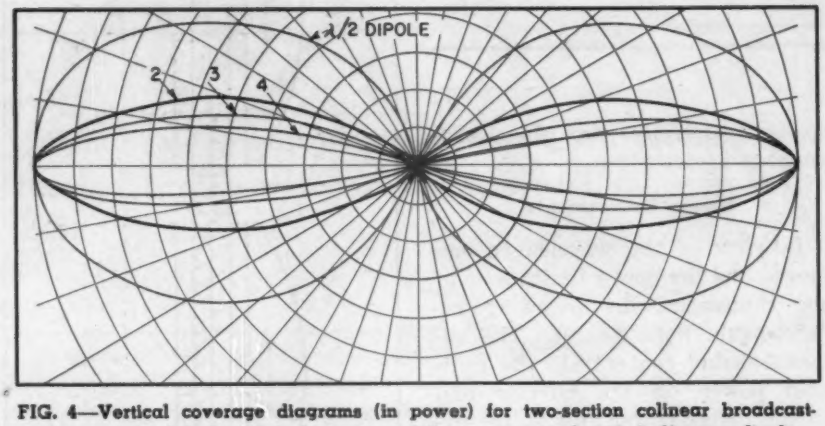


FIG. 4—Vertical coverage diagrams (in power) for two-section colinear broadcast-type arrays of 2, 3 and 4 elements at 465 mc, compared with half-wave dipole

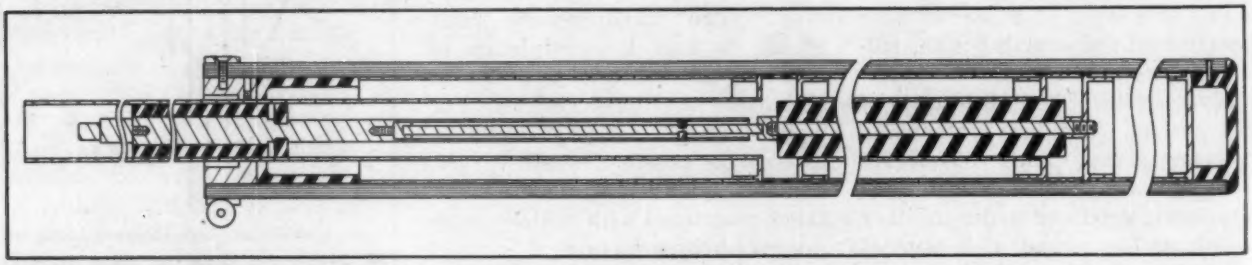
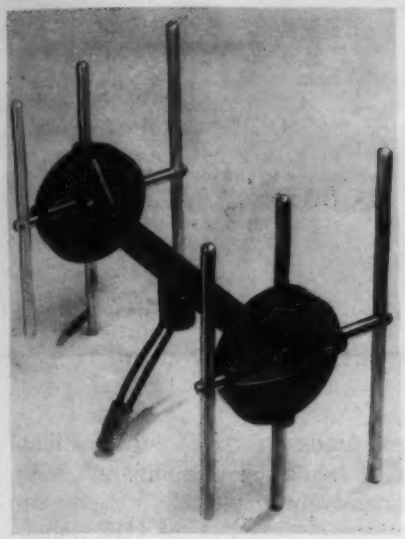


FIG. 5—Internal mechanical structure of the two-section colinear antenna. The heavy cross hatching indicates polystyrene dielectric



Six-element array designed especially for Electronics citizens radio project

The mechanical features of a two-section array are shown in the accompanying photographs. A weatherproof shield (actually a radome) of compressed fiberglass tubing is mounted over the array to protect it. This covering has negligible effect on the performance. Polystyrene spacers are used to keep the elements in proper relative positions. The two-section array is about 30 inches long. A five-section array, having a power gain of over five would extend about 6½ feet. While the colinear array is intended primarily for broadcast coverage, several arrays may be placed parallel to one another, or in front of a reflector, to produce a narrow pattern in azimuth.

Six-Element Array

A more conventional design suffices for a multi-element array for point-to-point service. A six-element array designed for the project is illustrated in the photographs. The elements are of half-inch aluminum tubing, the driven elements being mounted in molded low-loss plastic. The lengths of the elements are: director, 10¾ inches; driven element, 12 inches; reflector, 13 inches. The spacings are: director to driven element, 3 inches; driven element to reflector, 4¼ inches. The two sets of elements are parallel, 12½ inches apart.

The driven elements are fed by two one-foot lengths of 70-ohm polyethylene insulated coaxial cable, which are connected in parallel across the standard female fitting for RG-8/U cable. This array has a vertical beam width of 68 deg between half-power points and a horizontal width of 64 deg, with negligible side lobes, as shown in Fig. 6. The corresponding power gain is about 7 to 8 db relative to a single dipole. If two such antennas are used at the terminals of the communications system, the overall gain is 15 db, or 30 times in power, relative to dipoles. The voltage standing wave ratio lies between 1.0 and 1.2 over the band from 460 to 470 mc.

Both types of antenna are intended for convenient mounting on a hollow pole or pipe as shown in the accompanying illustrations. As used in current tests, the radiators are mounted on a setback on the north face of the McGraw-Hill Building in New York, about 450 feet above street level. Standard RG-8/U 52-ohm cable is used for the transmission lines. The nominal attenuation of this cable at 465 mc is 5 db per hundred feet, so cable lengths have been kept under 20 feet. Tests now under way will be reported in an early issue.

One problem in the application of antennas to the citizens service is the question of switching between transmitter and receiver. In mobile installations it is desirable to employ but one antenna. If the antenna is shunted across both transmitter output and receiver input, impedance matching difficulties are encountered. However, this problem can be circumvented by the use of switching.

Coaxial Switching

A satisfactory manually-operated switch is available (Bird coaxial switch, model 74), which consists of a short section of coaxial line, within a housing, which can be rotated by hand. The inner conductor is indexed to engage standard female fittings for RG-8/U cable attached to the housing. A six-position switch of this type has been employed successfully with four of the six terminals left unconnected. Manual operation is satisfactory for testing purposes, but for simplicity in operation an automatic switch is desirable. An investigation of the availability of such switches, with six-volt actuating relay coil, has revealed that at least one manufacturer has a coaxial switch of suitably low loss for the purpose. It is planned to secure such a switch and test it with the antennas here described.

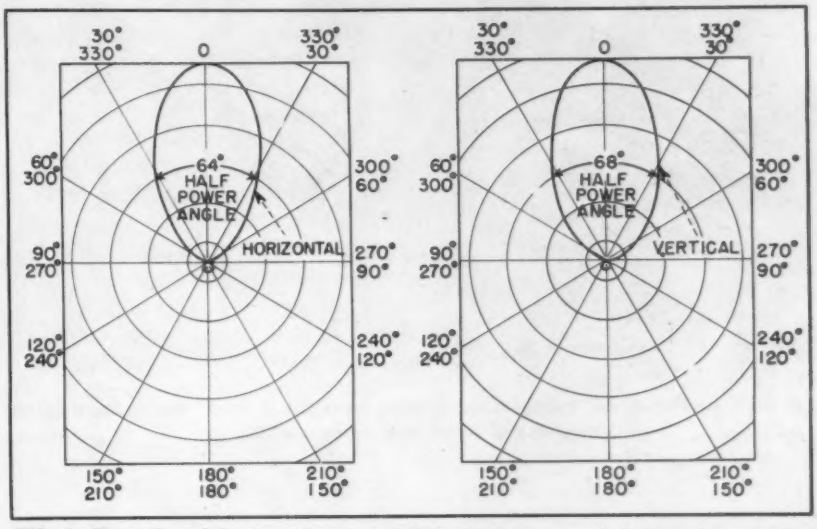


FIG. 6—Vertical and horizontal power directivity diagrams of 6-element array for point-to-point service

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(1) Electronics Sponsors Citizens Radio Project, ELECTRONICS, p 80, November 1947.

(2) W. C. Hollis, Transmitter for the Citizens Radio Service, ELECTRONICS, p 84 November 1947.

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STAGGER-TUNED

By HENRY WALLMAN

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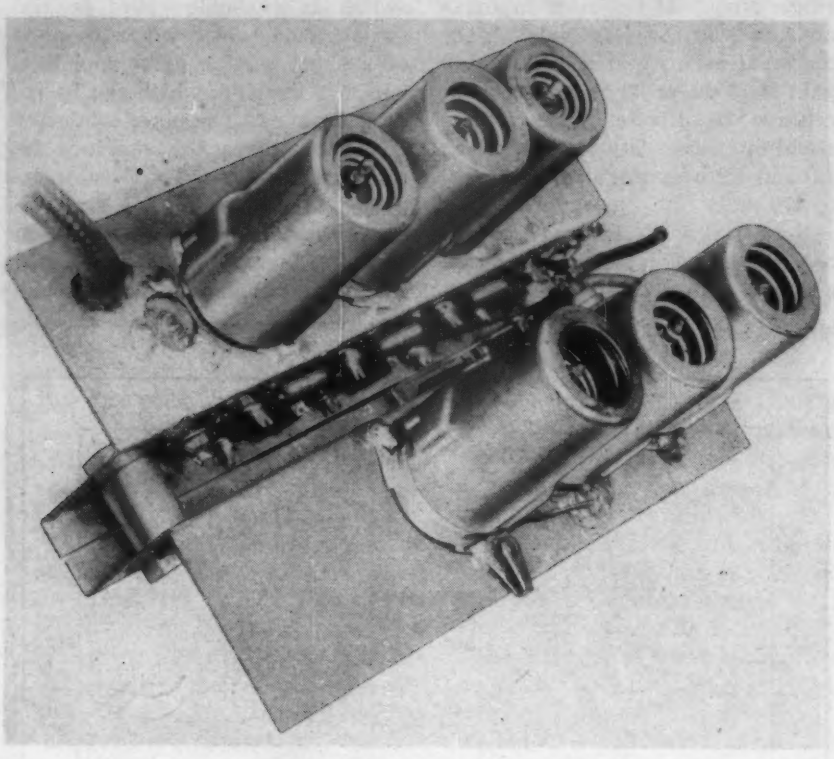
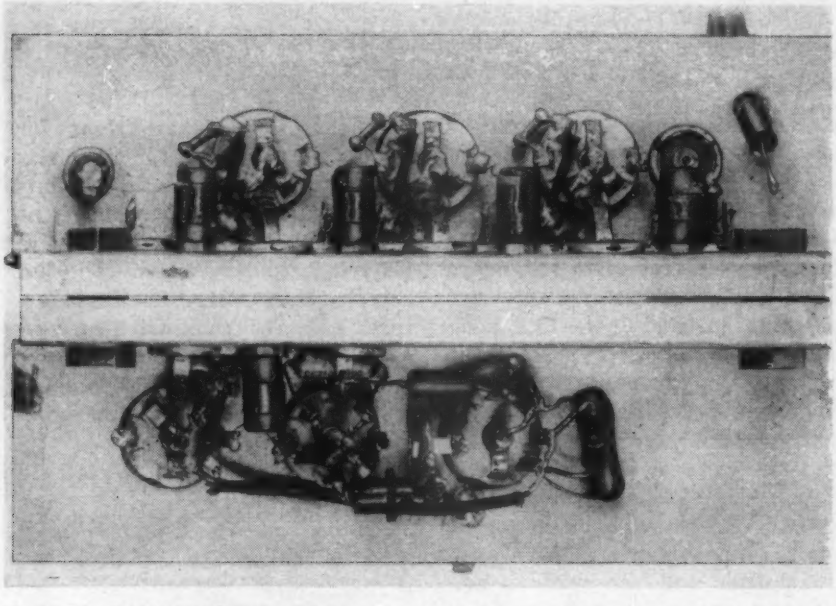


Four-stage, staggered, flat quintuple using 6AK5 tubes has a 10-mc bandwidth, a center frequency of 30 mc, and a gain of 10,000



View of underside of 30-mc amplifier shows how layout simplifies construction; a 6AL5 detector and 6AK5 pulse amplifier are included

STAGGER-TUNED intermediate-frequency amplifiers were extensively employed in radar receivers designed at the MIT Radiation Laboratory. These amplifiers had gains of 100 db and bandwidths (between low and high frequencies at which the gain was 3 db down from maximum) from 6 to 12 mc, although one amplifier had a bandwidth of 35 mc. Such amplifiers were satisfactorily produced in quantity by factory methods. This article summarizes design formulas for simple stagger-tuning schemes, presents curves of step response of certain of these circuits, and discusses practical considerations[1, 2].

Single-Tuned Circuit

The simplest i-f interstage network is a single-tuned circuit the usual connection of which is shown in Fig. 1A, and the equivalent form in Fig. 1B. The effective load resistance R is the parallel combination of the plate resistor R_L, the plate resistance of the first tube, the input resistance of the second tube, and the equivalent parallel loss resistance of the inductance L. The capacitance C is the sum of the output capacitance of the first tube, the apparent input capacitance of the second tube, the self capacitance of L, and the wiring capacitance. With careful wiring and a fixed tuned inductor about the size of a one-watt resistor, the value of C between two 6AG5 tubes is about 12 pf (picofarad is a micromicrofarad).

The bandwidth of the single tuned circuit is $1/(2\pi RC)$ and is independent of center frequency. The voltage amplification at band center is $g_m R$ where g_m is the tube

Amplifier Design

Practical wideband amplifier considerations, limits to overall bandwidth of cascaded stages, and transient response characteristics of stagger-tuned circuits are prevented. Curves and tables give design criteria. Comparisons are made to other coupling circuits

transconductance. The amplification-bandwidth product (figure of merit), denoted by AB, is $g_m/(2\pi C)$. For a g_m = 4,500 micromhos and C = 12 pf, as with conservatively rated 6AG5 tubes, AB is 60. An amplification of 6 with a bandwidth of 10 mc, or an amplification of 15 with a bandwidth of 4 mc is thus attainable in this case. Because the AB product depends only on the tube, being independent of center frequency, it is no easier to build a single-tuned amplifier covering the band from 28 to 30 mc (B = 2 mc) than one from 8 to 10 mc (B = 2 mc) with a given tube (except for the effect of smaller inductor size on interstage capacitance).

Synchronous Single Tuning

The simplest wideband i-f amplifier employs cascaded single-tuned stages all of the same bandwidth and resonant frequency. This synchronous tuning method is simple, noncritical, and has excellent transient response. Figure 2 shows the envelopes of the responses of combinations of synchronous single-tuned stages of 2-mc bandwidth to a step function of a sinewave at the center frequency of the amplifier. (All transient responses shown in this paper can be applied to other bandwidths by using the fact that speed of response is inversely proportional to bandwidth; the responses are for the centered, or double-sideband case.)

The disadvantage of the synchronous single-tuned amplifier is its low efficiency, resulting from the rapidity with which overall bandwidth shrinks as stages are cascaded. For example, for an overall amplification of 10,000, a synchronous single-tuned amplifier employing a tube that gives an AB = 60 has a maximum overall bandwidth of 7.1 mc, and requires 18 stages; the use of more stages yields an even smaller bandwidth.

Overall bandwidth for N synchronous single-tuned stages is to a very good approximation

$$\frac{\text{bandwidth of single-tuned stage}}{1.2\,(N^{1/2})}$$

To illustrate this relation, consider a cascade of 5 synchronous 6AG5 single-tuned stages, each of 10-mc bandwidth. If AB is taken to be 60 and the amplification per stage to be 6 (giving a bandwidth per stage of 10 mc), the overall amplification is 7,800, but, from the above expression the overall bandwidth is only 3.5 mc.

Stagger-Tuned Coupling

This shrinkage of bandwidth can be avoided while preserving the simplicity and low cost of single-tuned coupling by stagger tuning. For an overall bandwidth B, it is possible to stagger tune N single-tuned stages so as to achieve a center-frequency stage-amplification of A with AB still equal to $g_m/(2\pi C)$. Note that here B is the *overall* bandwidth and A the *gain per stage.*

The stagger-tuned passband for which $AB = g_m/(2\pi C)$ has a selectivity characteristic $1/(1 + x^{2N})^{1/2}$ where x is a variable proportional to the deviation of the frequency from resonance. The general shape of curves of this sort, which are called maximally flat, is shown in Fig. 3 for a common bandwidth of 2 mc. As N increases, the curves become squarer and flatter. Stagger-tuned couplings of this sort where N = 2, 3, 4, . . . , are called staggered pairs, triples, quadruples, etc.

Figure 3 also shows envelopes of responses to a step function of the band-center frequency. For the same bandwidth, but with increasing N, these envelopes show increasing overshoot, increasing delay, and somewhat slower rise.

In almost all cases, a passband with small dips is substantially superior for either optimum selectivity or optimum AB to a maximally flat passband, while for small overshoot, a more rounded curve is preferable. The only advantage of the maximally flat curve, apart from its mathematical simplicity, is its easily recognized shape when aligning amplifiers with a swept-frequency generator.

Table I shows the center frequencies and bandwidths to which individual coupling circuits should be designed to obtain flat-staggered amplifiers of overall bandwidth B at center frequency f_0. The data are presented in terms of the fractional bandwidth B/f_0. The values shown are valid only when B/f_0 is small, less than 0.3 for practical purposes. The exact case, which holds even for B/f_0 greater than unity, is fully considered elsewhere.[1,2]

An example will make the use of Table I clear. Suppose a flat-staggered quintuple consisting of an input circuit and four interstage circuits is desired at f_0 = 30 mc with an overall bandwidth B = 10 mc. Then B/f_0 = 0.3, and the quintuple consists of four tubes and five single-tuned circuits that satisfy the following conditions:

(1) the first should have a bandwidth of 19 mc at 30.0 mc, and

Table I—Flat Staggered Combinations

Bandcenter = f_0, overall bandwidth = B, and $B/f_0 < 0.3$

Number of Circuits	Component Single Tuned Circuits Center frequency	Bandwidth
Staggered pair (2)	$f_1 = f_0 + 0.35B$	$0.71(B/f_0)f_1$
	$f_2 = f_0 - 0.35B$	$0.71(B/f_0)f_2$
Staggered triple (3)	f_0	B
	$f_1 = f_0 + 0.43B$	$0.5(B/f_0)f_1$
	$f_2 = f_0 - 0.43B$	$0.5(B/f_0)f_2$
Staggered quadruple (4)	$f_1 = f_0 + 0.46B$	$0.38(B/f_0)f_1$
	$f_2 = f_0 - 0.46B$	$0.38(B/f_0)f_2$
	$f_3 = f_0 + 0.92B$	$0.19(B/f_0)f_3$
	$f_4 = f_0 - 0.92B$	$0.19(B/f_0)f_4$
Staggered quintuple (5)	f_0	B
	$f_1 = f_0 + 0.29B$	$0.81(B/f_0)f_1$
	$f_2 = f_0 - 0.29B$	$0.81(B/f_0)f_2$
	$f_3 = f_0 + 0.48B$	$0.31(B/f_0)f_3$
	$f_4 = f_0 - 0.48B$	$0.31(B/f_0)f_4$

Table II—Bandwidth vs Amplification

Tube type assumed to have $g_m/(2\pi C) = 60$; listed amplifications do not include effect of input network

Number of Amplifier States	Overshoot (see text) in percent	Bandwidth in mc for Gain of 10^3	Bandwidth in mc for Gain of 10^4	Gain for Bandwidth of 2.5 mc	Gain for Bandwidth of 4 mc	Gain for Bandwidth of 10 mc
Input plus 2 interstages						
3 synchronous single tuned	0	0.9	0.3	150	58	9
flat staggered triple	8.2	1.9	0.6	580	225	36
over staggered triple with 1 percent dips	10.2	2.2	0.7	800	310	50
3 flat double tuned with equal Q loading	7.7	1.9	0.6	580	225	36
3 flat double tuned with one sided loading	7.7	2.7	0.8	1,200	450	72
Input plus 3 interstages						
4 synchronous single tuned	0	2.6	1.2	1,100	290	19
2 flat staggered pairs	6.2	4.8	2.2	7,000	1,700	110
flat staggered quadruple	10.9	6.0	2.8	14,000	3,400	220
4 flat double tuned with equal Q loading	8.4	5.6	2.6	11,000	2,800	180
4 flat double tuned with one sided loading	8.4	7.9	3.7	32,000	7,800	510
Input plus 4 interstages						
5 synchronous single tuned	0	4.2	1.9	7,700	1,200	30
flat staggered pair plus flat staggered triple	10	8.9	5	16×10^4	25,000	630
flat staggered quintuple	12.8	10.7	6	33×10^4	50,000	1,300
5 flat double tuned with equal Q loading	9.2	9.4	5.3	20×10^4	30,000	770
5 flat double tuned with one sided loading	9.2	13.2	7.4	79×10^4	12×10^4	3,100
Input plus 5 interstages						
6 synchronous single tuned	0	5.3	3.3	42,000	4,000	41
3 flat staggered pairs	7.7	10.7	6.8	14×10^5	14×10^4	1,400
2 flat staggered triples	11.2	13.0	8.2	37×10^5	36×10^4	3,600
2 over staggered triples with 2 percent overall dips	14.5	16.1	10.2	11×10^6	11×10^5	11,000
6 flat double tuned with equal Q loading	10	12.6	8.0	32×10^5	31×10^4	3,200
6 flat double tuned with one sided loading	10	17.8	11.2	18×10^6	17×10^5	18,000

(2) the second, a bandwidth $0.81 \times 0.3 \times 32.9 = 8.0$ mc at 32.9 mc
(3) the third, a bandwidth $0.81 \times 0.3 \times 27.1 = 6.6$ mc at 27.1 mc
(4) the fourth, a bandwidth $0.31 \times 0.3 \times 34.8 = 3.2$ mc at 34.8 mc
(5) and the fifth, a bandwidth $0.31 \times 0.3 \times 25.2 = 2.3$ mc at 25.2 mc

If each tube has an AB of 60, the amplification per stage is 6 and the overall amplification is $6^5 = 1{,}296$.

Staggered Pairs and Triples

A flat-staggered pair has the same selectivity curve ($N = 2$ in Fig. 3) as a critically coupled double-tuned circuit. For such circuits, the overall bandwidth shrinks less rapidly as stages are cascaded than for synchronous

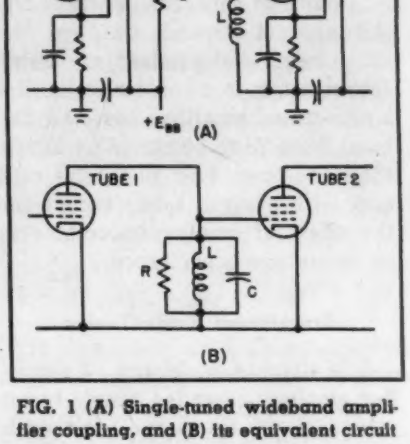


FIG. 1 (A) Single-tuned wideband amplifier coupling, and (B) its equivalent circuit

single-tuned circuits. The overall bandwidth for M flat pairs is

$$\frac{\text{bandwidth of single flat pair}}{1.1\,(M^{1/4})}$$

To illustrate this relation, consider a 6-circuit amplifier consisting of 3 flat-staggered pairs ($M = 3$). For an overall bandwidth of 10 mc, each pair must have a bandwidth of $10 \times 1.1(3^{1/4}) = 14.5$ mc. If AB is 60, the stage amplification is therefore 4.1.

A flat-staggered pair, a flat double-tuned circuit, and a flat inverse-feedback pair have the same transient response, because they are of the minimum phase shift type and have the same amplification-vs-frequency curves. The envelopes of the response to a step function of band-center frequency of amplifiers consisting of 1, 2, 3, 4,

and 6 flat-staggered pairs, or flat double-tuned circuits, or flat inverse-feedback pairs, each of 2-mc bandwidth, are given in Fig. 4.

It is interesting to examine the transient response of a staggered pair as the amount of staggering increases (or equivalently, of a double-tuned circuit as the coupling is increased above the critical value). Figure 5 shows the fractional overshoot of the response envelope to a step function of band-center frequency. The curve shows that, from the viewpoint of transient response, there is nothing critical about the flat selectivity curve.

A flat-staggered triple has the same selectivity curve ($N = 3$ in Fig. 3) as a flatly coupled triple-tuned circuit. For such circuits, the overall bandwidth for M flat triples is

$$\frac{\text{bandwidth of single flat triple}}{1.06\,(M^{1/6})}$$

To illustrate this expression, consider a 6-stage amplifier consisting of 2 flat-staggered triples ($M = 2$). For an overall bandwidth of 10 mc, each triple must have a bandwidth of $10 \times 1.06(2^{1/6}) = 11.9$ mc. For $AB = 60$ the amplification per stage is therefore 5.1. Figure 6 shows the envelope of the response of 1, 2, and 4 flat-staggered triples (or flat triple-tuned circuits, or flat inverse-feedback triples) of 2-mc bandwidth to a step function of band-center frequency.

Overstaggered Circuits

Appreciable increases in AB result from overstaggering the stages to yield pass bands with slight dips. For example, if a 6-stage amplifier consisting of 2 triples is over staggered so as to have 2 percent dips in the overall passband of the composite amplifier, there results an increase of fully 25 percent in amplification per stage over the flat-staggered triple amplifier of the same overall bandwidth; however, the transient response is degraded.[8] Table II summarizes the characteristics of various coupling combinations, showing, for 5 interstage networks, the effect of overstaggering. (For values of AB other than 60, for which the table is computed, the bandwidths should be multi-

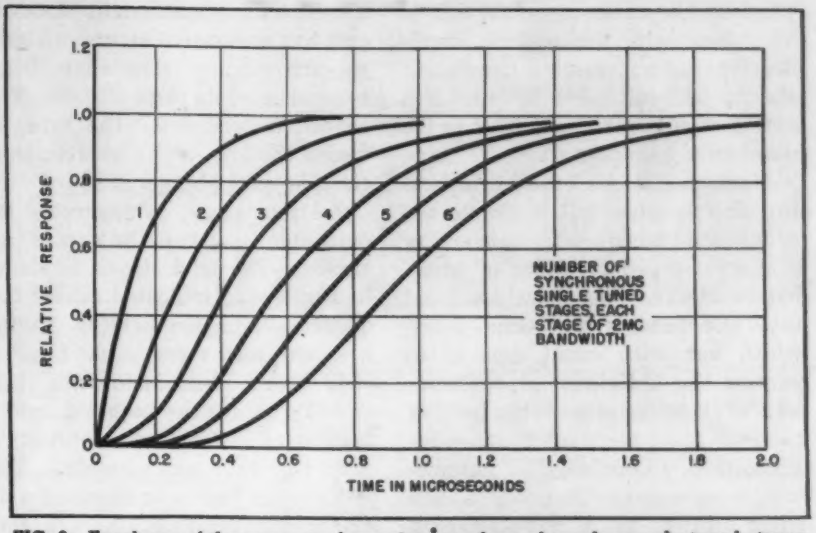


FIG. 2—Envelopes of the responses by various numbers of synchronously tuned stages to a step function input on a carrier at band-center frequency indicate the degree to which sharp pulses will be degraded in the amplifier. This family of curves should be compared to those of Fig. 3, 4, and 6. For example: the time taken for the outputs to rise through the middle 60 percent of their amplitudes are: about 0.5 microsecond with no overshoot for synchronous tuning, 0.3 microsecond with 10 percent overshoot for minimum phase shift networks, 0.4 microsecond with 12 percent overshoot for flat staggered pairs, and 0.4 microsecond with 8 percent overshoot with flat triples, all having a 2-mc bandpass. Table II gives the gains obtainable from these amplifiers

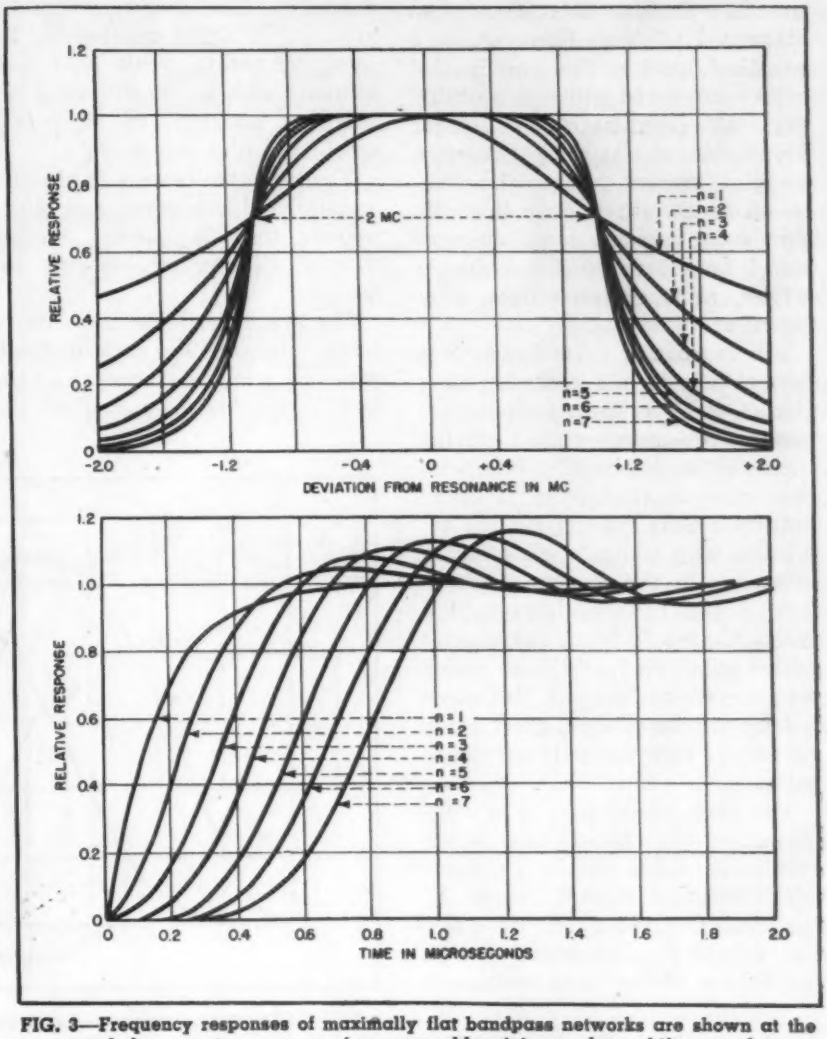


FIG. 3—Frequency responses of maximally flat bandpass networks are shown at the top; below are step responses for comparable minimum phase shift networks

plied by the ratio of actual AB to 60. Similarly, the overall amplifications for given bandwidth should be multiplied by the Nth power of this ratio, where N is the number of amplifier stages.)

Many variations of overstaggering are possible, but a simple approximate procedure for converting a stagger-tuned amplifier of given bandwidth that has a flat passband into one having the same bandwidth but with small dips is to narrow the individual stage bandwidths all in the same ratio, leaving the individual resonant frequencies unchanged. Considerable narrowing is necessary to produce any effect; thus, in a flat-staggered triple, the individual stage bandwidths have to be reduced 30 percent to produce 1-percent dips.

Practical Considerations

For a given overall bandwidth, a staggered sextuple has somewhat greater amplification than two staggered triples. However, as a practical matter, the combination of two staggered triples is probably preferable because of the smaller overshoot and less critical reaction to misalignment, unless the fractional bandwidth is close to unity. For such reasons, most stagger-tuned amplifiers employ pairs or triples, although sometimes quintuples are used.

For reasons of noise figure, it is desirable to have a centered input circuit, and overload considerations suggest a centered circuit driving the detector, if possible; otherwise the order of staggering is unimportant. Gain control can be applied to any stage or combination of stages in the staggered amplifier. Except for detuning resulting from changes in input capacitance with variation of grid bias, which was never serious in Radiation Laboratory experience, there is no reason for applying gain control to pairs.

The plate resistor R_L in a stagger-tuned stage should have whatever value yields the design bandwidth for that stage. Usually R_L is somewhat greater than the effective damping resistance R, but it can be less if the input resistance of the following tube is negative. Because of grid-plate capacitance, a tube having a resonant plate circuit has a negative input resistance at frequencies somewhat below resonance of its plate circuit. This condition occurs for the tube between the low- and high-frequency circuits of a staggered pair.[4]

A four-stage, staggered, flat quintuple using 6AK5's was designed. The final circuit is shown in Fig. 7, the indicated center frequencies and bandwidths having been obtained from Table I for $N = 5$, with a 10-mc bandwidth at 30 mc. To obtain the required amplification of 10,000, an amplification of 10 per stage was necessary. The 6AK5 tubes had to be operated with $AB = g_m/(2\pi C) = 100$. In this amplifier C was 10 pf; therefore g_m had to be 6,280 micromhos, exceeding the rated value by 25 percent. The special application of this amplifier justified operating the tubes in such a manner as to produce the required g_m. Had they been operated at a g_m of 5,000 micromhos, the same bandwidth would have been attained with an amplification per stage of about 8, or an overall amplification of only 4,000.

The tuning coils were fixed tuned on powdered-iron cores, and bifilar wound, that is, unity coupled, thereby eliminating blocking capacitors.

The space available necessitated folding the amplifier back on itself, with the input connection and the first three stages on half of the chassis, and the fourth i-f amplifier, detector, and pulse amplifier on the other half, as shown in the pictures. The two halves were separately wired, each half having greater accessibility than otherwise because of its open L-shaped chassis. The two halves were then connected with metal bushings, and the cover put over the combination. The only wire connecting the two halves is that from the secondary of the transformer following the third stage to the grid of the fourth, the return path being the inside of the metal bushing containing this wire. Use of feed-through, button, bypass capacitors mounted in the chassis wall made it possible to have only two components (tuning

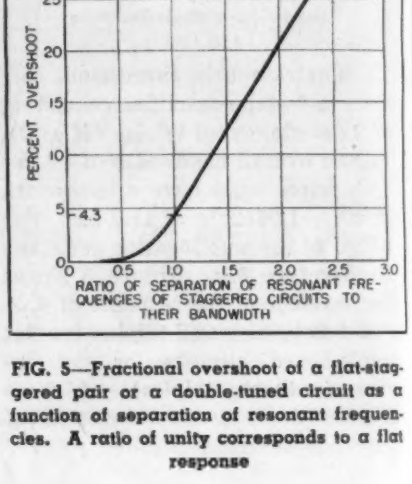


FIG. 5—Fractional overshoot of a flat-staggered pair or a double-tuned circuit as a function of separation of resonant frequencies. A ratio of unity corresponds to a flat response

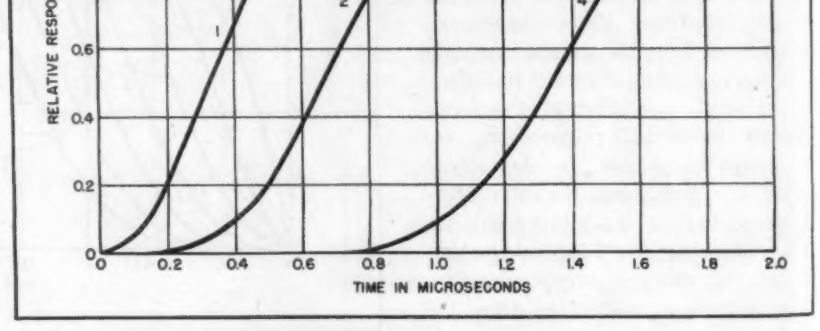


FIG. 4—Response envelope of flat-staggered pairs, flat double-tuned circuits, or flat inverse-feedback pairs

transformer and damping resistor) per i-f amplifier stage in the interior of the chassis. Decoupling resistors were situated on the outer side of the vertical chassis wall between the halves.

Where the fractional bandwidth is too large for Table I, exact formulas must be used.[5]

For very low frequencies such as those at the lower end of the audible spectrum, stagger-tuned amplifiers using stages employing selective R-C degeneration with twin-T networks, which have selectivity curves approximating those of single-tuned L-C networks, can be designed to give sharp cut-off without using heavy iron-cored inductors.[6]

Another means for obtaining high-gain wideband amplifiers is to use single-tuned circuits with resistive feedback,[7] the *AB* performance being equivalent to that of stagger tuning, except that the inverse feedback produces a slight reduction in effective transconductance, generally negligible unless the bandwidth exceeds about $0.3g_m/(2\pi C)$.

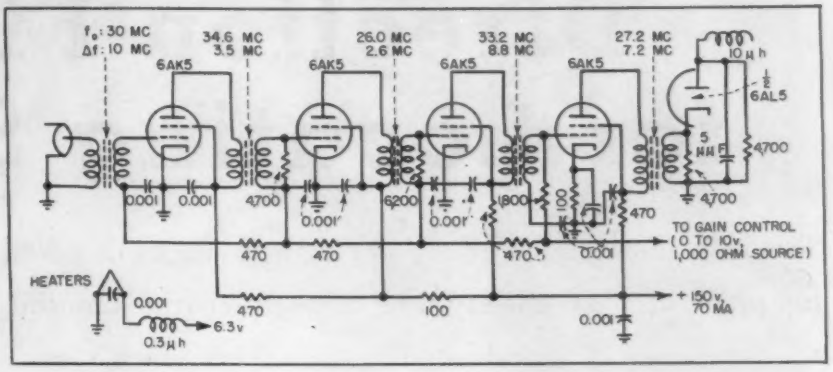


FIG. 7—Circuit diagram of four-stage amplifier pictured at beginning of article

Comparison of Methods

Table II shows that (1) synchronous single-tuned circuits are extremely inefficient, (2) flat-staggered pairs are slightly less and flat-staggered triples slightly more efficient than flat double-tuned circuits loaded to have equal primary and secondary Q, and (3) flat-staggered combinations are less efficient than flat double-tuned circuits loaded on one side only.

Inverse feedback and stagger-tuned amplifiers have the advantage over doubly-tuned amplifiers of considerably cheaper coil construction, which is their only significant advantage, apart perhaps from the smaller size and smaller capacitance to ground of the single-tuned inductors. The greater ease of aligning singly tuned stages over doubly tuned ones is thought by some to be an advantage favoring stagger tuning. Actually, because of their mechanical complexity and large capacitance, tunable coils are costly and degrade the performance of the circuit. Fixed tuned coils can be wound with sufficient accuracy and the wiring capacitance sufficiently accurately controlled by good mechanical design and layout to make factory tuning unnecessary for either type of coupling, and the amplifier is less subject to subsequent tampering. In addition, because the interstage coils are alike for all stages, inverse feedback and doubly tuned amplifiers have the advantage over stagger-tuned amplifiers.

However, inverse feedback has the disadvantage that gain control cannot be applied to a stage around which there is inverse feedback because it will change the bandwidth. On the other hand, gain control can be applied to any stage in a stagger-tuned or doubly tuned amplifier. Feedback resistors in inverse feedback amplifiers cannot be the ordinary half-watt type, but must be of a sort having considerably smaller end-to-end capacitance (such as the IRC type MPM).

The various coupling networks differ with regard to their sensitivity to the detuning that results from varying interstage capacitance. Doubly tuned circuits loaded on one side only are considerably more critical than doubly tuned circuits having equal primary and secondary Q, which is the principle objection to loading on one side only. In a stagger-tuned combination, the greater the number of different frequencies, the more critical it is.

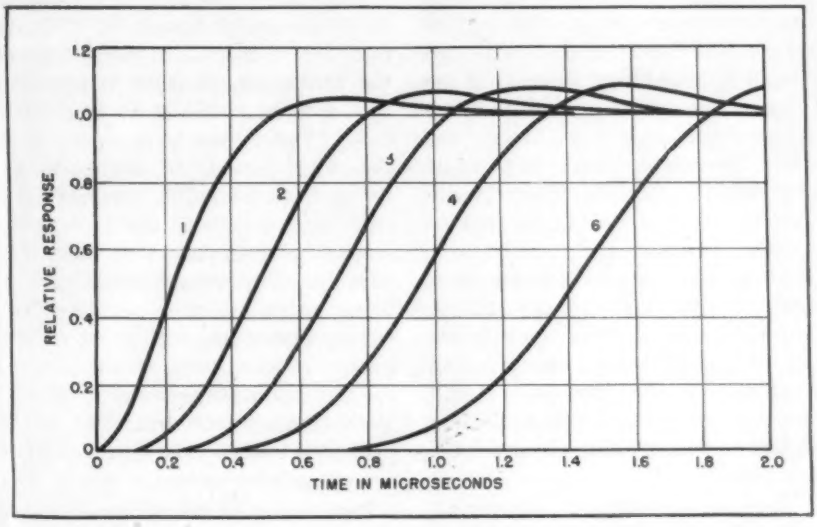


FIG. 6—Response envelope to a step function of band-center frequency of an amplifier of flat triples

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(3) Reference (2), Chapter 7.
(4 M. T. Lebenbaum, Wideband I-F Amplifiers above 100 Mc, ELECTRONICS, p 138, April, 1947.
(5) Reference (2), Table 4.3.
(6) Reference (2), Chapter 10.
(7) Reference (2), Chapter 6.

Direction Finder for Locating Storms

Two loop antennas placed at right angles to each other feed vertical and horizontal deflecting plates of a cathode-ray tube through separate amplifiers. Flash lines on tube screen indicate direction from which static is received

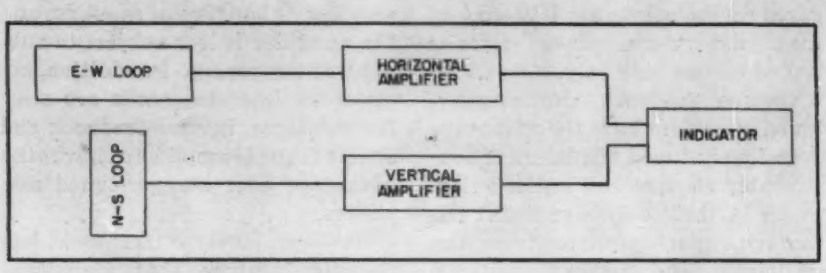

FIG. 1—Block diagram of the equipment. One of two identical amplifiers is shown

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LOCATING storm areas by means of the associated atmospheric static was first carried on in Europe about fifty years ago by Popoff, as mentioned by Bureau.[1] Twenty years later, the accuracy of measurement was greatly increased by Watson-Watt[2,3] and his co-workers in England. Subsequent work has been carried on by Munro[4] and co-workers in Australia, by Henderson[5] and his group at the National Research Council in Ottawa, by Lugeon[6] in Switzerland, and Weil[7], Mason[8], and Sashoff[9] at the University of Florida.

At the request of the Army Signal Corps, the equipment previously used at the University of Florida was redesigned and new units built for the location of storms.

Fundamental Principles

Atmospheric direction finding involves determining the direction of arrival of electromagnetic pulses associated with certain types of meteorological phenomena. The time variation of these pulses is of short duration and wide variety.

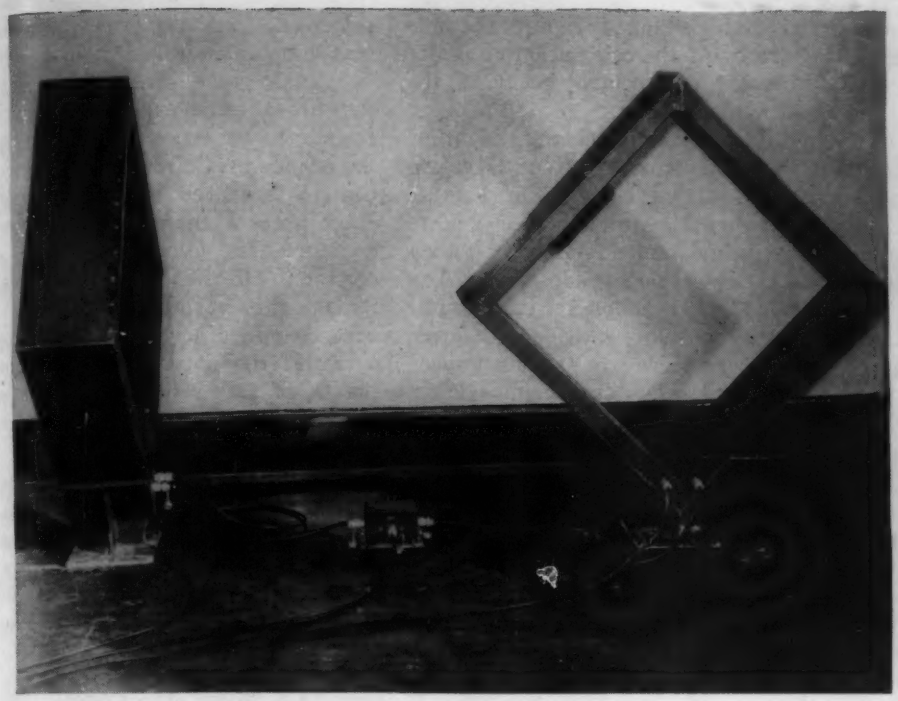
The transient nature of atmospherics makes it inadvisable to use conventional null-type direction finders for two reasons: first, the short duration of these pulses, rarely exceeding 5 milliseconds, makes impractical the proper orientation by either manual or mechanical means of the receiving antenna system within the time involved; second, the antenna system should not exhibit a blind azimuth in any direction at any instant if static pulses arriving at a rapid rate from random directions are to be received. The direction-finding device should be capable of indicating the direction of approach of the electrical disturbance at the instant the wave front sweeps past the point of observation. Consequently, the device to be described is an instantaneous direction finder.

Basically, the instantaneous static direction finder consists of two mutually perpendicular loops, the planes of which are oriented vertically in the north-south and east-west directions, two amplifiers and an indicating cathode-ray tube. See Fig. 1.

The signal voltages appearing across the output terminals of each loop are applied to the inputs of two nearly identical amplifiers. After suitable amplification, the output voltages corresponding to the north-south and east-west loops are applied to the vertical and horizontal deflecting plates, respectively, of the cathode-ray tube, giving a visible indication of the bearing of the incoming signal. See Fig 2.

Operating Frequency

Work by Austin[10] has indicated that the energy associated with atmospherics increases with decreasing frequency, at least to frequencies somewhat below 15 kc. Norinder[11] and others have shown that the quasi-periods of atmospherics range from 50 to 250 microseconds, with those pulses in the 150-microsecond category occurring most frequently. The energy contained in these pulses occupies a wide frequency spectrum, with most of the energy concentrated at the end of the spectrum corresponding to the quasi-frequency of about 7 kc. Since it is well known that such low-frequency electromagnetic waves are propagated with minimum attenuation over great distances, and since few longwave stations which would



East-west and north-south loops of the static direction finder

Developmental direction finder

produce interference operate at frequencies below about 20 kc, the choice of an operating frequency for the static direction finders of about 10 kc seemed advisable. Operations at frequencies below 10 kc would increase the bulk of the component parts of the resonant circuits and further decrease the effective height of the loop antennas.

Tuned circuits are used in the static direction finder to give the necessary selectivity for preventing interference from commercial stations and to increase the sensitivity. With tuned circuits the trace obtained on the face of the cathode-ray tube is not a reproduction of the incoming signal, but is a damped oscillation. This has the advantage of increasing the sensitivity, since the electron beam of the indicating tube makes a large number of excursions over the same path for each atmospheric pulse, building up the brilliancy of the indicated bearing. A single, or very few excursions of the electron beam would require greater accelerating voltages in the cathode-ray tube, with accompanying decrease in tube sensitivity. Both loops and one stage of amplification associated with each loop are tuned, with the loop circuits having the higher Q. Identical values of Q for both loops and for both tuned amplifier circuits are necessary if the received pulse is to produce a linear trace on the indicating tube.

Directional Antenna System

It was decided to use a multiturned, electrostatically shielded, balanced loop. Bearing angle tests with the loops were performed using the continuous-wave signals from NSS, located near Annapolis, Maryland, which operates on a frequency of 18.6 kc. The results of these tests showed that during the daytime the indicated bearing remained accurate and fixed to within 0.5 degree. At night, during turbulent ionospheric conditions, the indicated bearing was found to vary as much as 30 degrees from the fixed daytime value.

The loop antennas used with the AN/GRD-1 static direction finder (production models, designated AN/GRD-1A, were later made by the Airplane and Marine Instrument Company) are about three feet square and wound with 400 turns of No. 20 enameled-copper wire. There are four layers spaced 0.375-inch apart, each layer wound in two sections. The winding density of 20 turns per inch is obtained by grooved Formica spacers at the corners of the aluminum container which serves as the electrostatic shield. Additional spacers are used at the center of the span of each layer. The loops are wound in halves and grounded at the electrical centers. A 1-ohm precision resistor is placed on either side of the center tap to allow the injection of a signal from the calibration oscillator. The voltages appearing across these resistors simulate the induced electromotive force for alignment purposes. The buffer unit, two 100-ohm resistors between the loops in Fig. 3, provides sufficient attenuation between loops to reduce conductive coupling to negligible proportions.

Each loop has an inductance of 0.22 henry, a distributed capacitance of about 140 micromicrofarads and a measured Q of 40 at 10 kc. The loops are connected to the

input of each amplifier by means of two fifty-foot RG-22/U low-capacitance Twinax cables. Each loop is wound in an aluminum container whose cross section is broken in the usual manner to prevent the flow of currents reacting unfavorably upon the effective Q of the windings. These shields are sealed to keep out moisture. The loops are mounted ten feet apart, or more, since greater spacing has the advantage of making the mutual inductance adjustment for a minimum much less critical.

The Amplifiers

The final indicating device requires voltages whose components are in phase and whose magnitudes bear a direct relationship to the bearings of the approaching signal. These deflection voltages appear at the output of each amplifier and are the direct result of the loop voltages applied to the input of each channel.

Since the output voltage in an amplifier differs both in magnitude and phase from the input voltage, both the magnitude and phase of the output voltage must be easily and accurately controllable if the requirements imposed by the indicator are to be satisfied. Actually, because of a difference in deflection sensitivities of the cathode-ray tube, the gains of the amplifiers are not identical, but are so related to the deflection sensitivities as to compensate for this characteristic.

The effective bandwidth of each amplifier extends over a finite range and is designed to pass a damped wave train of various frequency components, so it is essential that the phase and amplification conditions at the center of the operating range be maintained in both channels over their effective bandwidths. A difference in phase shift between the two channels, or relative phase shift, may be due to three factors: first, the tuned circuits in the two channels may not be resonated to the same frequency; second, the tuned circuits may exhibit different values of Q; and third, the plate load impedance associated with each untuned stage may have a different time constant. These effects are indistinguishable from each other on the indicator at any fixed frequency; however, they are readily isolated by sweeping the frequency of the calibration oscillator through the central point of the operating range.

Since both channels are identical in construction, only one is reproduced in its entirety in Fig. 3. Across each loop is placed a large variable shunt resistance which makes possible a Q adjustment. The loop signal is coupled to each amplifier by means of a cathode follower which provides a high input impedance and a low output impedance. The high input impedance minimizes the loading effect on the high-impedance loop circuit, while the low-impedance output enables the coupling to be altered by a conventional potentiometer without introducing an objectionable phase displacement. Since the center of each loop is grounded, only half of the voltage developed by the loop is applied to the grid of the cathode follower. The grid resistor for this tube has a very high resistance, as its only function is to prevent the grid from becoming ungrounded if the loops are detached.

FIG. 2—Bearing indications for three successive static discharges

From the cathode-follower stage, the signal goes to contacts on switch SW_1, which is used during the alignment process and whose positions are indicated on the diagram. During normal operation this switch applies the signal to the grid of the untuned amplifier, a resistance-capacitance coupled stage in which the variable gain and a phase-shift control are placed. The gain of this stage is controlled by means of a variable cathode-dropping resistor which provides a variable positive voltage on the cathode. To prevent the tube from ever operating with zero bias, a fixed cathode resistor provides a small amount of self bias. This type of gain control was adopted in preference to conventional types since phase-shift difficulties were experienced with resistance variations across high-impedance grid circuits. The gain control is placed in the untuned stage since a change in transconductance is accompanied by a change in effective plate resistance. Should this variable plate resistance be placed across the resonant network, the damping, and hence the Q, of this circuit would be a function of the gain setting, which would be undesirable.

The possible difference in the time constants of the plate loads, due to a difference in the wiring capacitance, may be responsible for unequal phase shifts occurring in the untuned stages. To correct this difficulty, variable capacitors across the grid circuits of the tuned stages have been included. A correction made at any one frequency will hold over a wide range of frequencies.

From the untuned stage the signal is applied to a stage of tuned amplification employing a 6SK7 tube. This stage provides additional selectivity over that afforded by the tuned loops alone. As in the case of the tuned-loop circuit, this circuit must be provided with means for adjusting its Q. This is accomplished by placing a high variable resistance in shunt with the tuned circuit.

The signal is then applied to the transformer-coupled stage, which is used to provide a signal level adequate to deflect the beam of the cathode-ray oscilloscope. It is necessary to employ a series resistor in the grid circuit of this stage to eliminate the possibility of sustained oscillations which might result from the use of reactive elements in both the input and output circuits. The output transformer is mounted in the indicating unit in order to place the interconnecting cable on the low-impedance side of the transformer. The voltage from the secondary of this transformer is applied directly to the deflecting plates of the cathode-ray tube. The deflecting plates are driven through a balanced network to minimize defocusing of the electron beam. The manufacturing tolerances of the transformers are

such that it is necessary to provide small variable air capacitors across the secondaries to make the transformer characteristics more nearly identical. A difference in characteristics at this point introduces a phase shift similar to that arising in the untuned stage. During adjustment, switch SW_2 is closed, paralleling the grids of the last stages to insure identical signal voltages at this point.

Cathode-Ray Tube Indicator

The cathode-ray tube is mounted on a chassis which includes the usual positioning, focusing, and brilliancy controls in addition to the output transformers and the associated phase controls.

It is convenient to have the cathode-ray tube fixed so that one pair of plates is oriented vertically while the remaining pair is approximately horizontal, depending upon the degree of orthogonality existing between the deflecting plates. The manufacturing tolerances of most cathode-ray tubes are such as to require individual angular calibration of the face of each tube that is to be used. This difficulty is easily remedied by applying known voltages to both pairs of plates and marking the face of the tube to agree with the calculated angles. It is evident that this calibration procedure, in addition to correcting for the misalignment of the deflecting plates, also compensates for the difference in deflection sensitivities.

The equipment is provided with 5CP5 and 5CP7 cathode-ray tubes coated with short and long-persistence phosphors, respectively. The short persistence phosphor is employed during photographic observations, while the long-persistence phosphor is convenient when making visual observations.

Power Supply and Calibration

The power supply is conventional, consisting of a regulated low-voltage supply for the amplifier and calibration oscillator and high-voltage supply for the scope unit. The cathode-ray tube is operated at comparatively low accelerating potentials to render the maximum possible deflection sensitivity consistent with adequate brilliance. Both the 5CP5 and 5CP7 tubes require a positive voltage with respect to ground for the intensifier electrode in addition to the voltage applied to the accelerating electrode, which is negative with respect to ground. These two voltages of opposite polarity are readily obtained from a single high-voltage winding by the use of two half-wave rectifiers working on alternate half cycles, connected so as to deliver both a positive and a negative voltage with reference to a common ground.

The calibration oscillator is of the negative-transconductance two-terminal type with resistance tuning. The output voltage is delivered to the alignment switch across a T pad placed in the cathode circuit of a cathode follower. This prevents reaction from the output control upon the oscillator frequency. Sufficient reverse feedback is employed to maintain the output voltage constant to within 5 percent.

Alignment

One of the problems encountered during development of the matched amplifiers was the resolution of various factors responsible for the observed relative phase shifts and, therefore, different pulse response characteristics. During a change in frequency of the calibration oscillator, the variations of the traces obtained on the cathode-ray tube are such as to make possible the recognition of these various causes.

Figure 4A illustrates the pattern appearing on the face of the indicator tube due to a difference in time constants of the plate loads and, hence, phase displacements, in the untuned stages, where the load impedance consists of the coupling resistance and the wiring reactance in parallel. The slopes of the major axes and the eccentricities of the family of ellipses remain constant, while only the magnitudes of the ellipses change during variations in the frequency of the calibration oscillator. Figure 4B depicts the phase-shift variation with respect to frequency for these stages.

The pattern observed if the tuned circuit of either the loops or the tuned stages are not tuned to the same frequency is illustrated by Fig. 5A. The major axis of the dotted ellipse is shown as a dashed line. As the frequency of the calibration oscillator is swept across the transmission band of the amplifiers, the solid figure gives the locus of the extremities of the major axis of the changing ellipse. The slope of the major axis of the ellipse changes in either direction about the normal 45-degree position, depending on whether the frequency of the calibration oscillator is above or below resonance. Figure 5B shows the amplitude relationships between the two channels for this condition.

Similarly, Fig. 6A shows the effect of a difference in Q of the resonant plate loads and, therefore, of the effective bandwidth of the amplifiers. Here the slope changes in one direction only, becoming more nearly vertical or more nearly horizontal, depending on whether Q_H is greater or less than Q_V. That this pattern is caused by a difference in bandwidth is further illustrated in Fig. 6B. Here it can be seen that the unidirectional change in slope occurs because of the in-

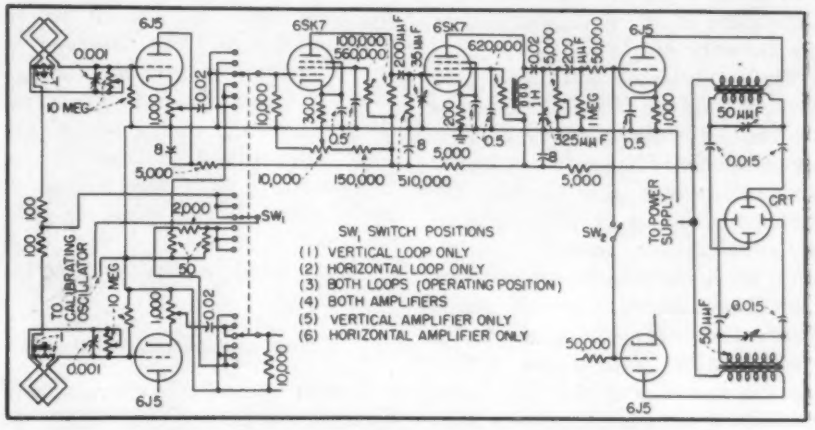


FIG. 3—Circuit diagram of the static direction finder

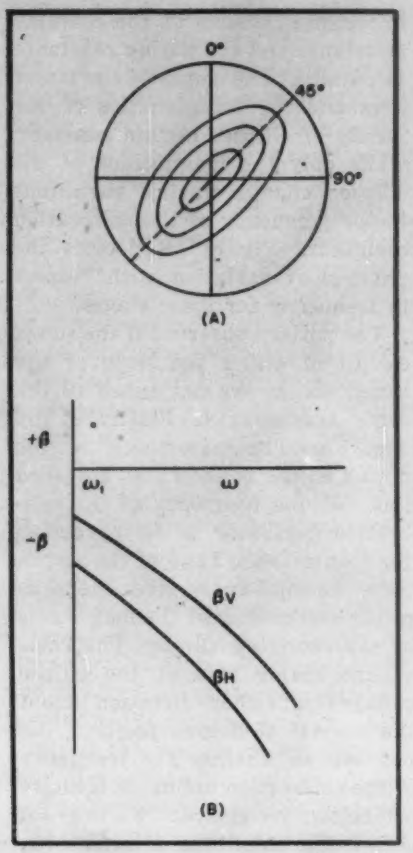


FIG. 4—(A) Pattern for various calibration oscillator frequencies when product of reactance and resistance, or time constant of untuned N-S amplifier stage plate load impedance is not equal to that of E-W amplifier. (B) Corresponding phase variation

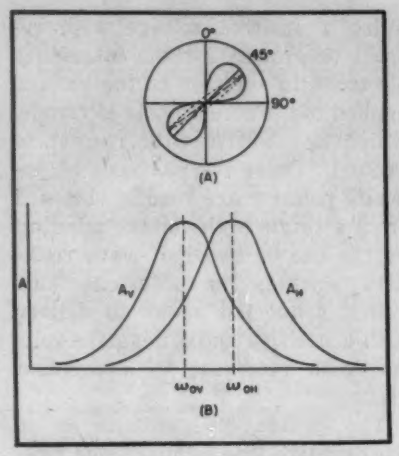


FIG. 5—(A) Pattern for successive settings of calibration oscillator frequency when resonant frequency of vertical amplifier differs from that of horizontal amplifier. (B) Corresponding gain variation between amplifiers

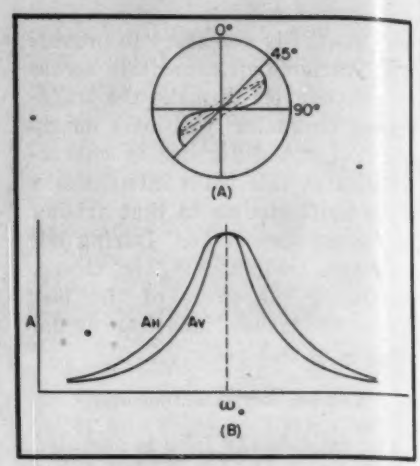


FIG. 6—(A) Pattern for successive settings of the calibration oscillator frequency when the Q of the resonant circuit in the vertical amplifier is not equal to that of the horizontal amplifier. (B) Corresponding gain variation between amplifiers

herent symmetry of the response curve and because the response of one channel falls off more rapidly than the other.

Networks for Storm Location

For the location of storm areas a network of three, or preferably four, stations with base lines 500 to 1,000 miles long is employed. The storm areas are located by triangulation of the data obtained by the network stations.

The angular orientation of a flash on the face of the scope can be determined either visually or photographically. The visual method of observation has the obvious advantage of being rapid, with data on simultaneous flashes immediately available at the end of each run. The disadvantages of visual observations are the uncertainty of accurately reading the flashes and the question as to whether the method of sampling used was adequate for location of storms within the range of the network. In general, only a small percentage of the total number of flashes appearing on the scope are read by the visual method. The photographic method has the advantage of recording all flashes, but the film record requires processing before the information can be transmitted to a central point for triangulation.

The operational procedure of the development network was as follows. Runs of from 10 to 20 minutes duration were made every two hours, while all stations were in constant radio communication with one acting as the control station. When the observer at the control station noted an observable flash, a signal was transmitted to the network stations where each observer recorded the angular orientation of the flash immediately preceding the signal. This was possible with the use of the long-persistence cathode-ray tube. In case of doubt, where multiple flashes were observed at one or more stations, no readings were recorded. Immediately after the conclusion of each run, the data were transmitted to the control station where they were plotted on gnomonic projection maps. In general, only those readings were used which resulted in three-station intersections.

Acknowledgment

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Bridge-Balanced AMPLIFIERS

Inherently stable with respect to tube and supply-voltage variations, the d-c voltage and current amplifier circuits described lend themselves ideally to the design of vacuum-tube voltmeters and photoelectric light meters

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THE MAXIMUM sensitivity obtainable with a vacuum-tube voltmeter is limited by the stability that can be achieved. The difficulty in maintaining an accurate zero base line is due to these major causes: (1) variations in values of the circuit parameters, such as resistances; (2) variations of supply voltages; (3) variations of tube factors, such as plate resistance and amplification factor.

Variations in circuit parameters result chiefly from changes in temperature of resistors. They can be minimized by the use of thermally compensated resistors and the proper placement of component parts. Fluctuations of line voltages affect both the heater and the plate supply voltages. Tube factors are dependent upon operating voltages, upon cathode emission, and upon the aging of the tube. The effect of variations in supply voltages and tube factors on zero deflection of the output meter can be minimized by the use of balancing circuits.

Voltage Amplifier

Figure 1 shows the basic circuit of a d-c bridge-balanced voltage amplifier. Tube T_N serves as an inverse-feedback amplifier in which the degeneration is provided by the I-R drop across the bias resistor R. Other tubes, T_1 to T_{N-1}, serve to balance out variations of tube factors and supply voltages.

The cathodes of all tubes are heated from the same source. The balance will be perfect if all tubes remain identical in characteristics as supply voltages and other conditions change. Physically, R_1, R_2, T_N, and other tubes of the amplifier circuit perform as the four arms of a balanced bridge, in which R_1 and R_2 correspond to the ratio arms, T_N to the unknown arm, and $T_1 - T_{N-1}$ to the standard arm. Any change in voltage drop across the arm T_N due to variations in tube factors or in supply voltages will be accompanied by an identical change in voltage drop across each tube of the

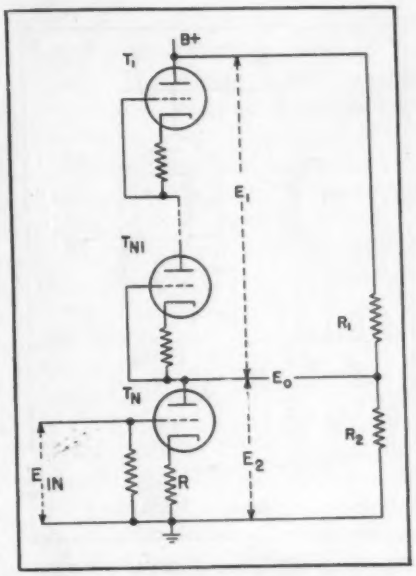

FIG. 1—Basic circuit of d-c bridge-balanced voltage amplifier

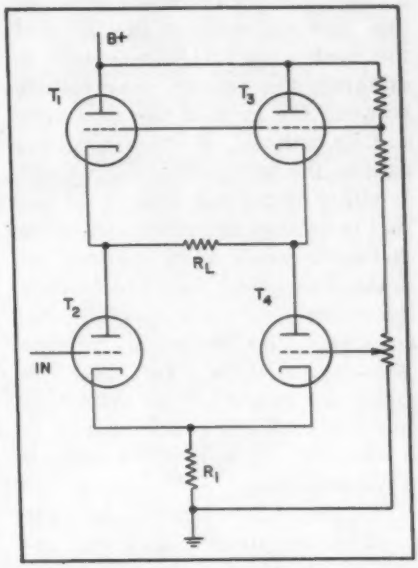

FIG. 2—Basic circuit of d-c bridge-balanced current amplifier

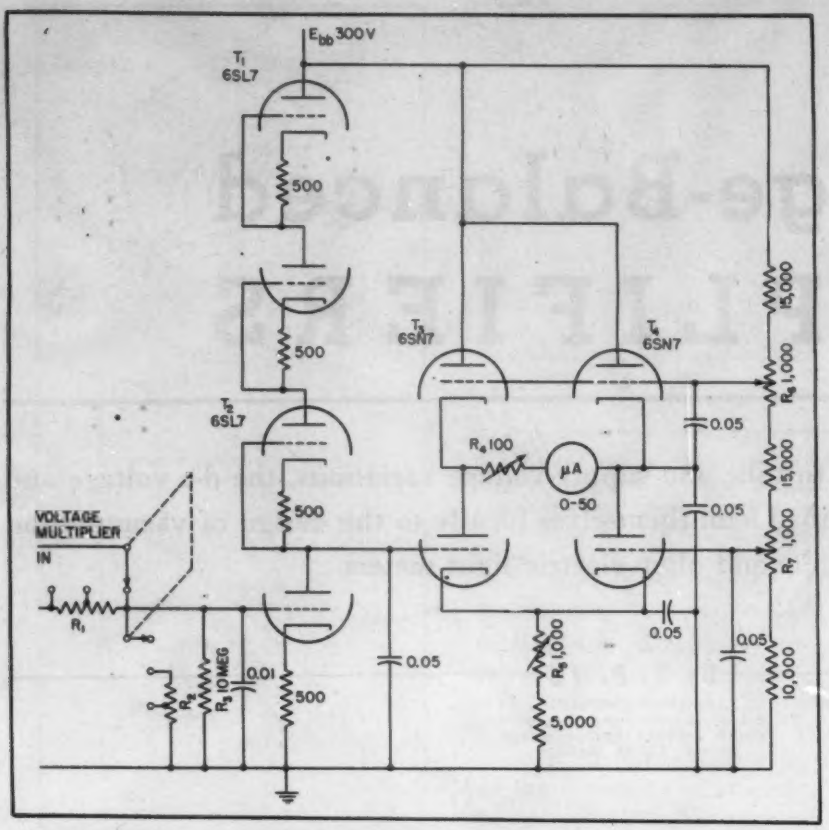

FIG. 3—Circuit of practical vacuum-tube millivoltmeter employing a balanced amplifier to obtain extreme stability

arm $T_1 - T_{N-1}$; therefore, the ratio of E_1 to E_2 remains constant, and the balance of the bridge holds for any part of the tube curves.

Current Amplifier

The output terminals of the bridge-balanced voltage amplifier are at high quiescent d-c potential above ground. In order to couple this output directly to the input of the next stage, it is necessary to establish the correct bias voltage between the grid of the next tube and its cathode. Furthermore, the gain of the bridge-balanced voltage amplifier decreases rapidly as the load resistance decreases, becoming extremely small when the load resistance is lower than the cathode resistance R because excessive degeneration is developed by the cathode resistors. In order to couple the output to an indicating meter of low internal resistance, it is necessary to reduce the amount of degeneration.

The d-c bridge-balanced current amplifier circuit of Fig. 2 was developed to satisfy these requirements. In this circuit the correct grid-bias voltage of T_2 is established by the voltage drop across resistor R_1, and the amount of degeneration is reduced by eliminating cathode resistors. The grid-excitation voltages of T_3 and T_4 are opposite in phase. Therefore, the signal components of plate currents of T_3 and T_4 cancel in the biasing resistance R_1; there is no loss in amplification even when R_1 is very large.

Millivoltmeter Circuit

The schematic diagram of a vacuum-tube millivoltmeter is shown in Fig. 3. Two 6SL7 tubes are used as a d-c bridge-balanced voltage-amplifier stage and two 6SN7 tubes are used as a d-c bridge-balanced current amplifier. Balance adjustment of the output stage is accomplished by adjusting the grid biases of T_3 and T_4. The potentiometer R_7 is used as a panel zero control. The potentiometers R_5 and R_6 are used to take care of large zero shifts such as may be encountered when the tubes are changed. An L-attenuator consisting of two resistors, R_1 and R_2, is used as a voltage multiplier to give a constant input resistance of 10 megohms at all voltage ranges.

Care in construction is essential in a sensitive vacuum-tube voltmeter of this type. It was found necessary to provide good ventilation, to choose tubes of similar characteristics, and to use low-temperature-coefficient precision resistors. Furthermore, the temperature coefficient of all resistors except R_1, R_2, R_3, and R_4 should be identical. Stabilization of the plate-supply voltage is obtained by the use of an electronic voltage-stabilizing circuit.

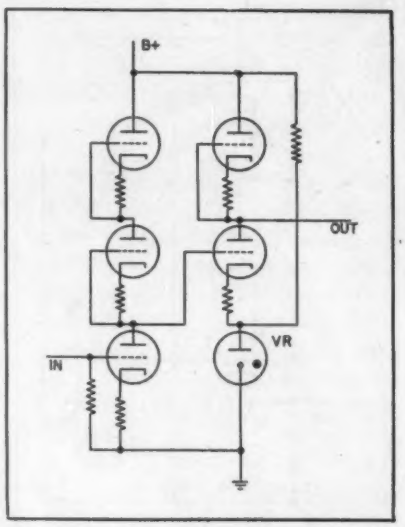

FIG. 4—Coupling two stages of a bridge-balanced amplifier by using a voltage-regulator tube

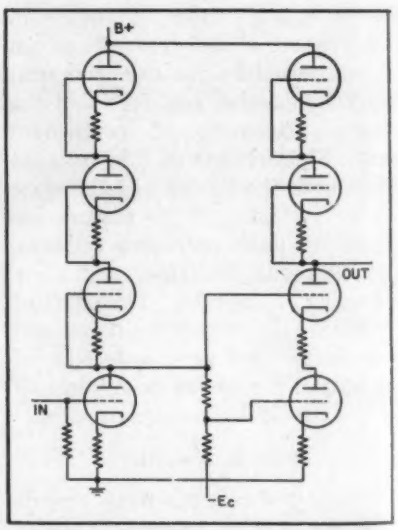

FIG. 5—Another method of coupling between stages in a d-c bridge-balanced amplifier

This instrument gives a full-scale meter reading of one millivolt d-c on its most sensitive voltage range. In conjunction with a special probe (diode detector), the instrument may be used to make exact measurements from d-c up to radar frequencies. By connecting the instrument across proper resistors a very sensitive microammeter is obtained. For example, it is possible to obtain a full-scale deflection for 0.001 microampere by connecting the instrument across a 1.111 megohm resistor, making the resultant input resistance one megohm. When used with an external battery and proper resistors, the instrument will measure resistances from 0.001 ohm up to 1,000,000 megohms. Line-voltage variations from 105 volts to 120 volts will affect the meter reading by less than 4 percent.

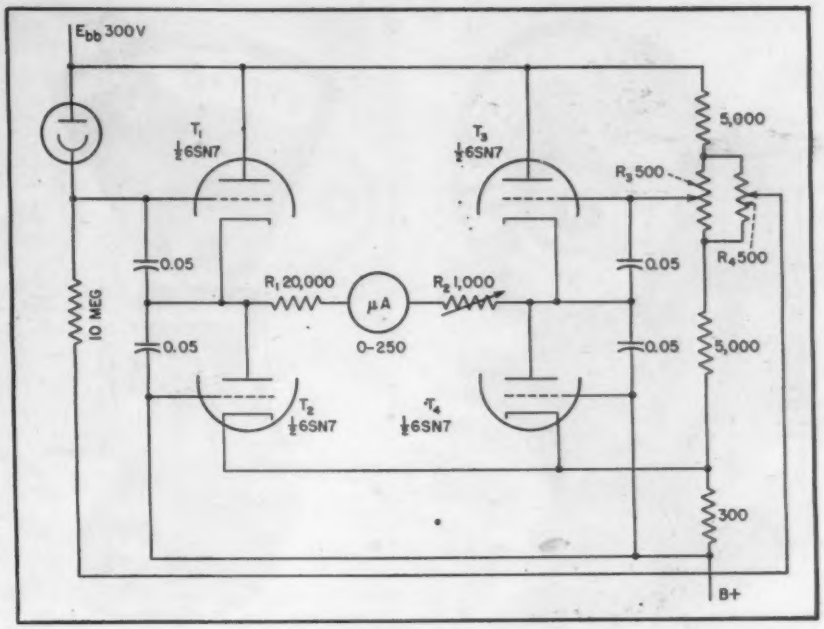

FIG. 7—Degenerative-balance light meter circuit employing a balanced amplifier to obtain high stability

Coupling Between Stages

When a single plate supply is employed, coupling between stages is one of the major difficulties in the design of multistage d-c amplifiers. Three methods which are particularly adaptable in bridge-balanced arrangements will be described here.

One method utilizes a cold-cathode voltage regulator tube as shown in Fig. 4. When all the tubes in the circuit are similar, the overall voltage gain of this amplifier is $\mu^2/3$, where μ is the amplification factor of the tubes. A voltage gain of 64 db with good stability was obtained from this amplifier circuit by using two and one-half 6SL7's. But noise is generated by glow discharge in the voltage regulator tube, and a highly regulated plate-supply is needed to give good stability to this amplifier.

The second method employs a separate bias-supply, as shown in Fig. 5. When all tubes are similar, the design equation of this amplifier is

$$R_1/R_2 = E_{B0}/E_0 = N-2$$

where N is the number of tubes in series, and E_{B0} is the quiescent plate voltage. The overall voltage amplification of this circuit is $\mu^2/2$, where μ is the amplification factor of the tubes. The disadvantage is that two highly regulated power supplies are needed.

The third method employs a push-pull phase-inverter arrangement wherein a large cathode bias may be employed without the usual attendant disadvantage of excessive negative feedback. The basic circuit of this type of arrangement is shown in Fig. 6. The overall voltage gain of this amplifier is $2\mu_1\mu_2/3$, where μ_1 and μ_2 are the amplification factors of the tubes employed in the first and the second stages respectively. A voltage gain of 56 db with very low noise level was obtained from this circuit by using one and one-half 6SL7's as the first stage and two 6SN7's as the inverter stage.

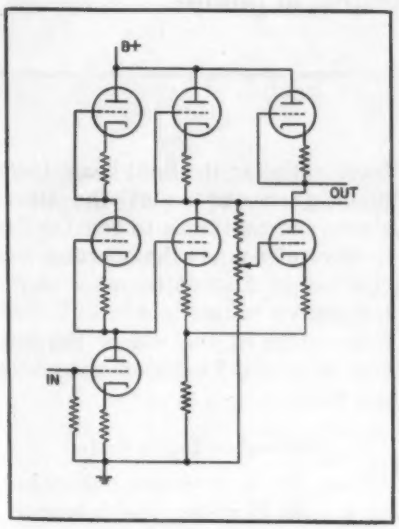

FIG. 6—Using a phase inverter to couple two stages improves amplifier performance

Light-Meter Circuit

A bridge-balanced circuit with negative feedback, for measurement of very small illumination, is shown in Fig. 7. The bridge arrangement of the circuit makes zero setting practically independent of supply-voltage variations. The amount of degeneration developed by resistor R_1 is sufficient to prevent tube changes from affecting the calibration of the instrument. This circuit can measure illumination with full-scale sensitivity corresponding to a phototube current of 0.5 microampere.

The process of balancing the circuit is simple. Connect the grid of T_1 to the center tap of potentiometer R_3, and adjust R_3 to bring the meter reading to its zero position. Then reconnect the grid of T_1 to its original position, and again bring the meter reading to zero by adjustment of R_4. The circuit is then ready for operation. Variable resistor R_2 is used for adjusting the calibration of the output meter in case it is necessary to change the phototube. Potentiometer R_4 is used as a panel zero control. This circuit has proved itself simple to build, reliable in indication, and stable in operation.

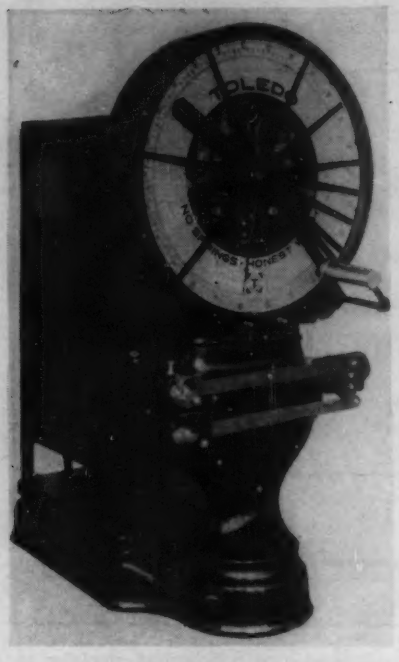

FIG. 1 — Conventional scale equipped with light source, phototube, interceptors, timer and tank to measure fuel used by airplane engines under test

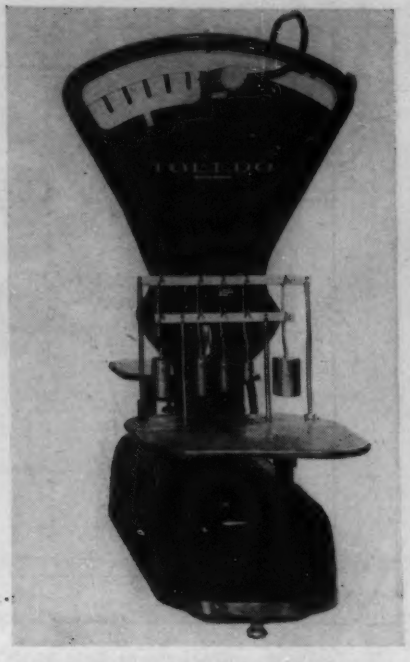

FIG. 2—Scale modified to check fuel consumption of automobile engines. Weights are automatically added as tank empties, to spread out readings

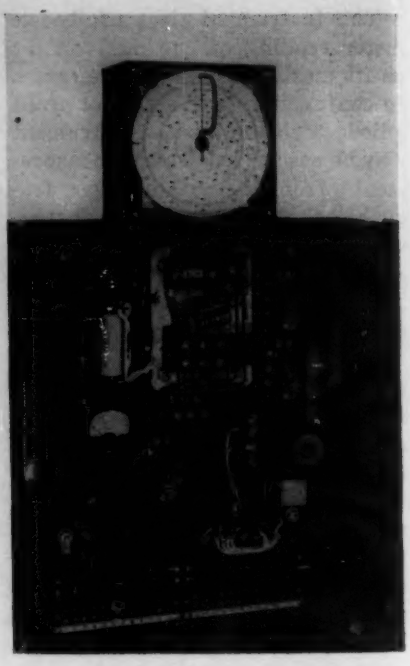

FIG. 3—Amplifier and relays of the scale used to measure fuel consumption of automobile engines. The timer, a separate unit, may be seen on top

Measuring Liquid Flow by Weight

Conventional scales are modified to accurately, automatically and quickly check fuel consumption of airplane and automobile engines under test by adding a photoelectric attachment, timer and tank. Method also lends itself to testing of pumps

DURING THE WAR a number of manufacturers expressed the need for an accurate means of measuring the fuel consumption of aircraft engines undergoing laboratory dynamometer tests. Scales such as the one shown in Fig. 1 were built for this application.

A narrow beam of light is focused on a slot in the scale chart and a phototube is mounted behind the slot. Interceptors which rotate with the scale indicator intercept the light beam at fixed intervals of weight. A synchronous motor-driven timer runs for a selected number of interceptions (selected weight sample). The fuel consumption is calculated from the size of the sample and the time required to use it.

A tank on the scale platform holds sufficient fuel for the maximum test sample. This tank is kept full, between tests, by means of a float valve. When the operator starts a test by pressing a button, a solenoid-operated valve in the tank supply line closes, so that all fuel used by the engine must come from the tank. The scale indicator moves clockwise and at the first interception of the light beam (zero reading on the scale) the timer starts and continues to run for the number of pounds the operator has chosen for the test (number of interceptions of the light beam). The timer stops at the end of the test and the solenoid valve opens to refill the tank.

Automobile Engine Tester

Since the war, several automobile companies have become interested in accurate methods of determining the fuel consumption of passenger-car and truck engines. The rate of

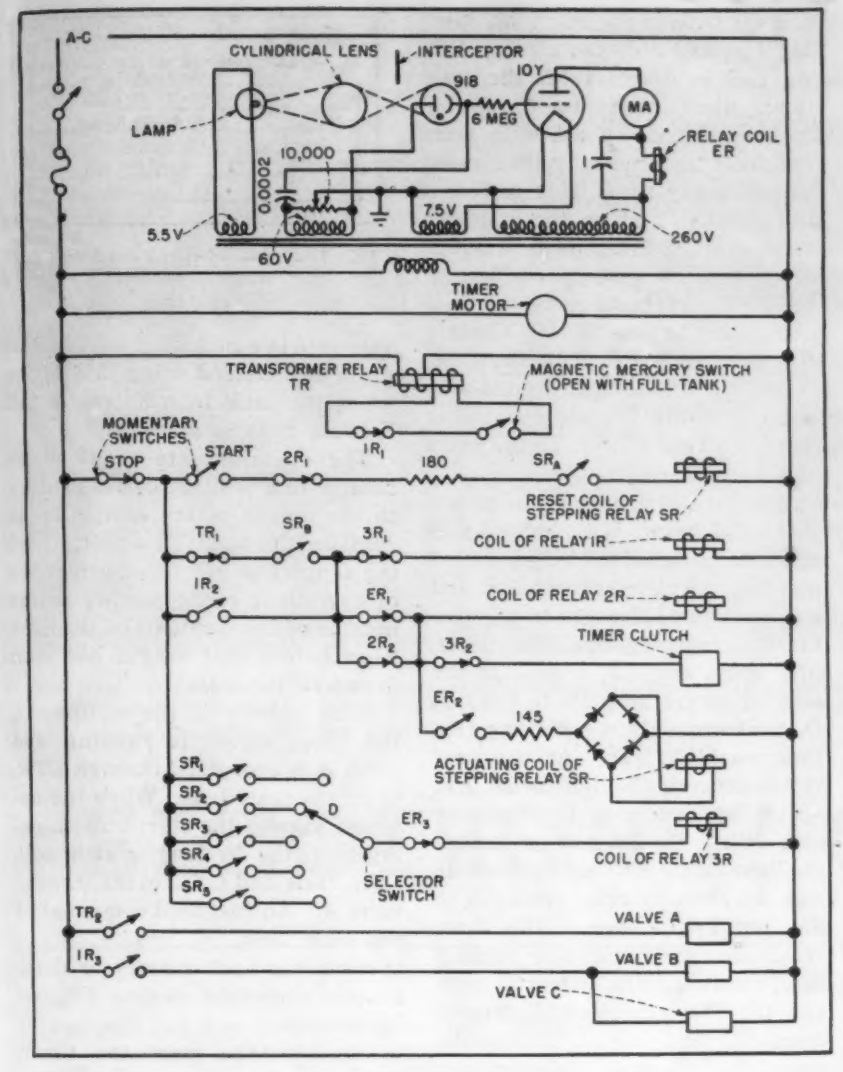

FIG. 4—Simplified circuit of the fuel-consumption tester. Six relays are used (*ER, SR, TR, 1R, 2R and 3R*). The various contacts of these relays are shown separated from their coils for clarity and are identified by subscript letters or numerals

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flow is much smaller than for large airplane engines, so special scale equipment is used as shown in Fig. 2.

A small tank is placed on the platform of the scale. Auxiliary weights are automatically added to the scale as the platform moves up with removal of fuel from the tank. This achieves an indicator travel of about two inches per ounce while weighing samples up to two pounds. The operation of the photoelectric attachment will repeat within less than ten-thousandths of an inch of indicator movement, so very accurate weighing of the sample can be accomplished.

To eliminate the need for computing rate of flow, a special timer was developed. This timer has five rows of graduations, one for each sample value, and is calibrated in pounds per hour. A sample weight is chosen which will require between one minute and two minutes for the test. With the following sample values, liquid flow in the range of five to 120 pounds per hour can be read directly on the proper timer dial circle:

Weight of Sample	*Range per Hour*
2 lb	120 to 60 lb
1.075 lb	64.5 to 32.25 lb
0.578 lb	34.7 to 17.35 lb
0.310 lb	18.6 to 9.3 lb
1/6 lb	10.0 to 5.0 lb

By using a straight time circle also printed on the timer dial, higher and lower values of flow can be computed.

It is not practical to use a float valve in a small tank, so the tank is filled to a definite weight between tests. A magnetically operated mercury switch is mounted inside the scale housing. This switch is operated by a permanent magnet on the scale indicator when the indicator has moved to a position corresponding to the full weight of the tank. The switch operates the transformer-type relay shown on the panel in Fig. 3 and this relay operates a solenoid valve in the supply line.

Circuit Principle

The photoelectric attachment is used for only on and off operation and the frequency of operation is quite low, so the equipment is quite simple. A simplified wiring diagram is shown in Fig. 4.

A gas-filled type 918 phototube is used with a single-stage amplifier, operating on alternating current. A telephone-type relay is used, with two snap-action switches as double-pole double-throw contacts, in the plate circuit of the amplifier tube. A plate-current milliammeter assists in focusing the light source

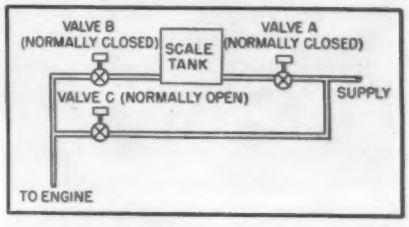

FIG. 5—Tank valve setup of Fig. 4

and also serves as an indication of when tube replacement is necessary. A filament-type amplifier tube is used in preference to a heater type so the equipment can be put into operation with no long wait for the cathode to heat up.

An available stepping relay had coils for 24 volts d-c. It was found that the reset coil would work satisfactorily on a-c for the momentary service required, so a series resistor was used to reduce the 110 volts to a satisfactory value. A copper-oxide rectifier, with resistor in series, was used to energize the stepping coil. Contacts SR_4 and SR_5 are off-bank contacts, SR_4 opening and SR_5 closing when the stepping relay is reset. Normally, before a test is started, SR_4 will be closed, SR_5 open and SR_1, SR_2, SR_3, SR_4, or SR_5 closed.

Operating Details

With power on the equipment, if the tank is not full the magnetic mercury switch is closed, so the transformer relay is operated, TR_1 being open and TR_2 closed. The engine can draw fuel through valve C, as shown in Fig. 5.

When the start button is pressed, the stepping relay resets, opening SR_1 through SR_5 and SR_4 and closing SR_5. When the tank is full the magnetic mercury switch opens, dropping out the transformer relay to close valve A and close TR_1. Relay contact $1R_2$ now comes in to seal around TR_1 and SR_5, open $1R_1$ to prevent the transformer relay operating and close $1R_3$ to open valve B and close valve C so all fuel comes from the scale tank.

While the scale tank is full, the phototube is illuminated. This reduces the negative bias on the grid of the amplifier tube, so the plate current pulls in the relay ER, opening ER_1 and ER_3 and closing ER_2. As fuel is drawn from the scale tank, the interceptor assembly moves and cuts off the light from the phototube, reducing its current to practically zero. This increases the negative bias on the amplifier tube grid and the plate current drops to zero (the bias-adjusting 10,000-ohm potentiometer permits adjustment to this value). Contact ER_2 opens and ER_1 and ER_3 close, pulling in $2R_2$ to seal around ER_1 and energizing the timer clutch to start the timer. This is the start of a test.

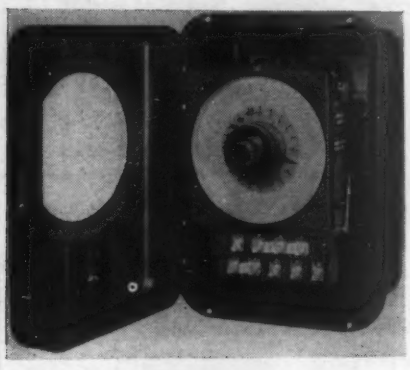

FIG. 6—Magnetic counter applicable to modified scale

When the first interceptor passes the light beam, the phototube is again illuminated, ER is again energized by the plate current, ER_1 and ER_3 open and ER_2 closes to energize the stepping relay coil. SR_4 closes, SR_5 opens and SR_1 closes. If the selector switch was set to position D, as shown (Fig. 4), nothing further would happen. At the next interception of the light beam, ER_2 opens to deenergize the stepping coil. When the interceptor passes the light beam, ER_3 again closes to step the stepping relay from SR_1 to SR_2, but ER_3 is open at this time. When the next interceptor darkens the phototube, ER_3 closes to energize $3R$. The opening of $3R_2$ deenergizes the timer clutch to stop the timer, and $3R_1$ opening deenergizes $1R$, breaking the $1R_2$ seal to drop out $2R$ for another test. The closing of $1R_1$ permits the transformer relay to come in, opening valve A to refill the scale tank. The opening of $1R_3$ closes valve B and opens valve C so the engine continues to run from the main supply. The operator records the fuel consumption (from the timer reading) and resets the timer to zero. He may then readjust the load on the engine, set the selector switch for a new value and press the start button for another test. The test will start as soon as the scale tank is filled and TR_1 closes.

Simplification

Although some users prefer a selector switch, a readily adjustable contact-operating magnetic counter shown in Fig. 6 and developed by the Eagle Signal Corporation permits simplification of the control.

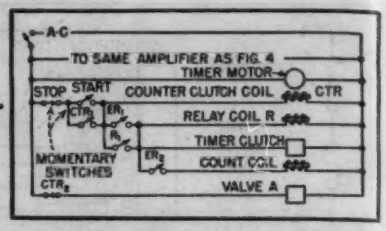

FIG. 7—Simplified circuit used with the magnetic counter

Figure 7 is a simplified wiring diagram of a method using this device when the tank is maintained full between tests by a float valve.

The operator sets the counter pointer to a position corresponding to the weight of the sample to be used for the test. This means that the counter is set for the number of operations corresponding to the number of interceptions of the light beam before that weight has been drawn off the scale.

With power on the equipment, the timer motor is running and valve A is energized through CTR_2 to fill the scale tank. When the operator presses the start button, energizing the counter clutch coil, CTR_1 seals and CTR_2 opens, closing valve A. All fuel used comes out of the scale tank.

When the first interceptor darkens the phototube, closing ER_1, relay R seals in and the timer clutch is energized to start the timer. When the interceptor passes the light beam, illumination of the phototube closes ER_2 to energize the count coil. Succeeding interceptions of the light beam deenergize and energize the count coil. When the count coil is deenergized after the preset number of operations, CTR_1 opens to drop out R and deenergize the timer clutch to stop the timer and CTR_2 closes to open valve A to refill the tank.

Other Uses

Equipment similar to that described is also used to test the performance of pumps. In this case, however, the liquid is generally weighed into the scale tank.

The valve is in the discharge line from the scale tank, so that between tests the liquid flows through the tank. When a test is started, the valve closes and interceptions of the light beam occur as the weight of liquid on the scale increases.

New organ-type electronic instrument uses conventional keyboard; and pipe organ playing and control technicques are directly applicable. Contacts located under the keys control individual vacuum-tube oscillators. To avoid humidity problems in hot and humid areas, windings have been potted where convenient, and coils have been wax impregnated

ELECTRONIC ORGAN

Keyboard controls 167 Hartley oscillators designed for grid-circuit keying and high stability of tuning. Separate loudspeaker channels minimize Doppler-effect distortion at cone. Power amplifiers have low intermodulation distortion

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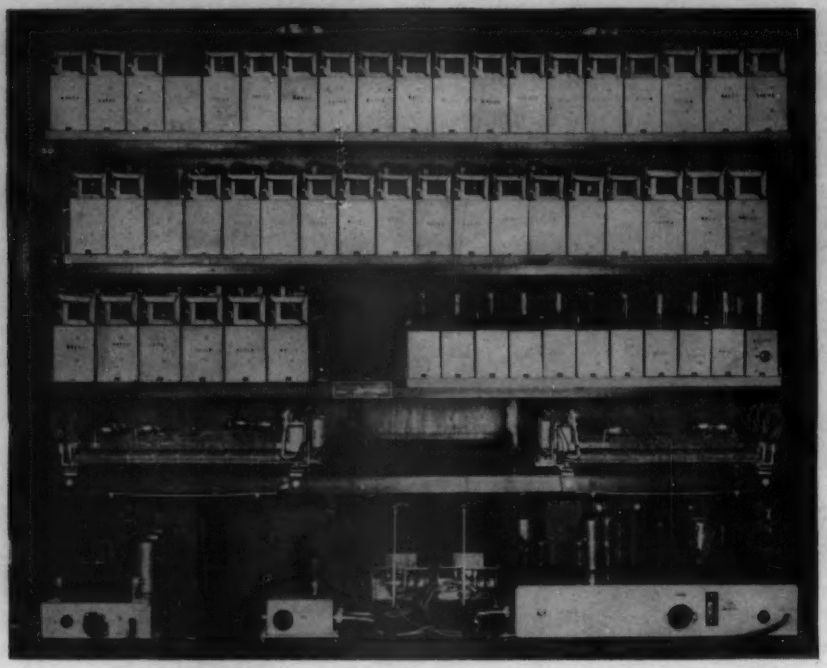
IN the organ-type electronic musical instrument to be described, each note of the keyboard corresponds to a Hartley oscillator arranged to provide a sinusoidal fundamental, devoid of harmonics, and a pulse signal that is rich in harmonics. Twelve additional oscillators provide an octave extension of the treble on the swell (upper) manual.

The various voices are derived from mixer circuits that mix the fundamentals and pulse signals in the proper proportions and subject the resultant to appropriate frequency-discriminating circuits to produce the desired formant. The outputs of the several mixers associated with any division of the organ (swell, great, or pedal) are mixed through buffer amplifiers. The resultant signal from each division is further amplified to recover the mixing loss and is passed through the volume control associated with the expression pedals.

The expression pedal controlling the volume of the swell manual voices also controls some of the pedal voices by means of a separate potentiometer having a range of control which is less than the range used on the manual voices. This compensates for reduced sensitivity of the ear at low sound levels in the pedal tones and maintains a satisfactory balance between these voices in the pedal division and those in the swell division over the complete range of the expression pedal. The other pedal voices are handled similarly on the expression pedal used for the great manual.

Following the expression pedals the outputs of the three organ divisions may be mixed together or kept separate as the installation may require. For a small room all three outputs may be mixed at the input of a power amplifier. For in-



Rear view of Connsonata with back panel removed to show assemblies of oscillators, mixers, and couplers. At bottom, left to right, are the coupler power supply, isolation amplifier, expression pedals, and power amplifier

stallations requiring more than one loudspeaker the signals from the pedal voices are amplified and fed to one or more pedal loudspeakers while the signals from the manual voices are either mixed into a common power amplifier and loudspeaker system or are fed into two separate systems.

The lowest frequency available in the pedal oscillators is the musical note C_1 (32.703 cycles per second). The lowest frequency produced by the manual oscillators is one octave higher, or 65.406 cycles per second. It has been found desirable to use separate power amplifiers and loudspeakers for the manuals and for the pedals. Power input to the pedal loudspeakers is limited by the cone excursion at the lowest frequency and the power input to the manual loudspeakers tends to be limited by the power-handling capacity of the voice coils.

This separation of loudspeaker channels practically eliminates the distortion inherently produced by the Doppler effect when medium or high frequencies are being radiated by a cone that is simultaneously executing low-frequency vibrations of appreciable amplitude. The further separation of the signals from the manuals, though not so necessary, does contribute to the elimination of this distortion that has long been associated with electronic instruments when played at high sound intensities, and also lends to the space effect that is highly desirable especially in large installations.

Oscillators

The Hartley type of oscillator with grid circuit keying was selected for a number of reasons: (1) such an oscillator provides a dependable tone signal generator that produces transient and steady-state effects in an independent fashion comparable to the tone generators generally used in the production of orchestral, vocal, or pipe organ music; (2) the oscillator can be keyed with the simplest type of switch and permits use of conventional pipe-organ couplers; (3) the oscillator can be produced and maintained at a reasonable cost.

Oscillator design requirements included: (1) high stability of tuning, especially with time and with temperature variations: (2) good keying characteristics for natural attack and release of tone; (3) satisfactory tremolo having the proper amount of amplitude, frequency, and quality change to compare with the tremolo or vibrato generally used in vocal music or by orchestral instruments; (4) proper and uniform tonal qualities with adequate amounts of natural harmonics available; (5) easy tunability; (6) simple, inexpensive construction.

The resulting oscillator, using half of a twin triode, is assembled on a four-note chassis as indicated in Fig. 1. The organ described here has 167 oscillators. Of these, 32 are associated with the pedals (notes C_1 to G_2), 61 are in the great division (C_2 to C_7), 73 are in the swell division (C_2 to C_8), and a special type of low-frequency oscillator is used as a source of tremolo frequency. The fundamental tone signals generated in the tank circuits

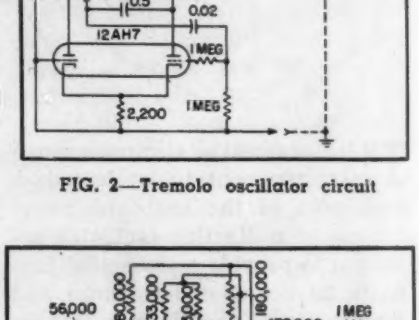


FIG. 2—Tremolo oscillator circuit

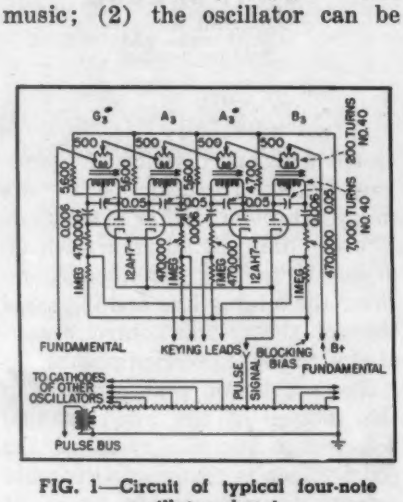


FIG. 1—Circuit of typical four-note oscillator chassis

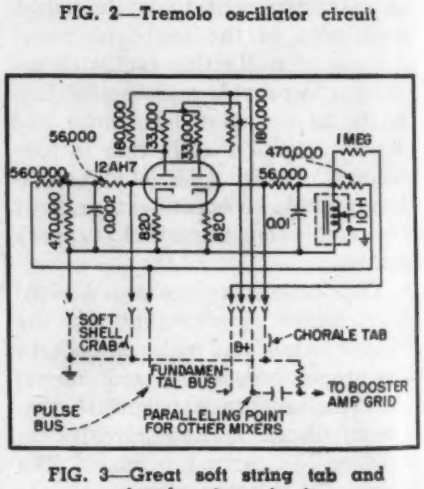


FIG. 3—Great soft string tab and chorale mixer circuit

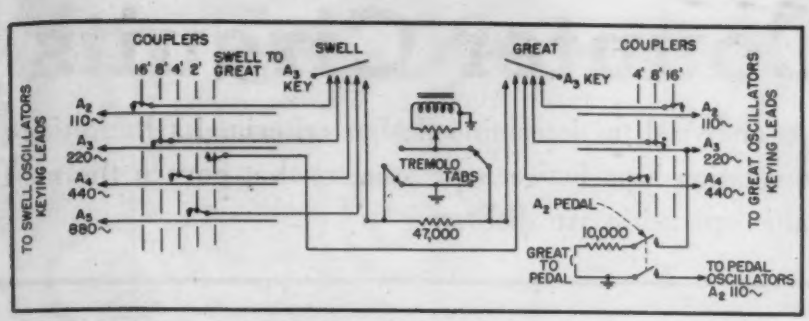


FIG. 4—Typical coupler circuit, with keying details for one key in each manual and one pedal key

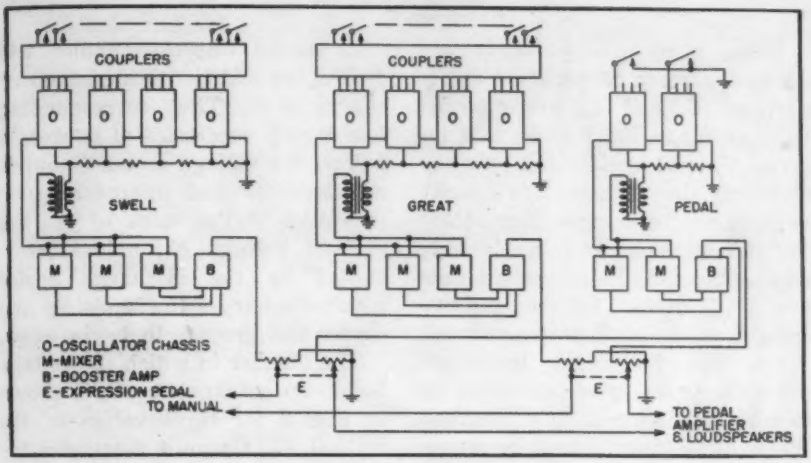


FIG. 5—Block diagram of model 2A, showing substantial independence of swell, great, and pedal organs. Most of the oscillators have been omitted here

are mixed in series for a given rank of oscillators, and the pulse signals are parallel-mixed.

The oscillator circuit constants are so chosen that plate and heater voltage variations will not appreciably affect tuning of the oscillators. The oscillator plate supply is, however, taken from a voltage-regulated source in order to provide a source having a low apparent impedance. This eliminates a tendency that would otherwise exist for the several ranks of oscillators to synchronize when the same note is played in each or to lock in exact octave relationship when octaves are played. This synchronization, if permitted by a sufficiently large common impedance in the plate voltage source, would seriously reduce the grand celeste or chorus effect that depends upon independent tone generators.

Tremolo Oscillator

The tremolo oscillator circuit in Fig. 2 feeds approximately 5 volts of low-frequency signal into a 1,500-ohm resistance. The tremolo frequency is adjustable through the range of 4.7 to 6.5 cycles per second by a resistance control.

Mixers

The mixers are single-stage amplifiers that mix the proper amounts of fundamental and pulse signals together and determine the formant for the proper tonal character of each voice. Each voice is controlled from a conventional tablet switch on the console. This switch short-circuits the grid of any mixer to ground when the voice is not wanted. The output circuits of the mixers associated with one division are paralleled. The circuit of a typical mixer chassis which includes two mixers, soft string, and chorale is given in Fig. 3.

The coupler arrangement, as applied to the A_3 keys of the great and swell manuals and the A_2 key of the pedals, is shown in Fig. 4. The oscillators are keyed by grounding the keying leads either directly or through the tremolo generator output. Any key is able to control several oscillators through appropriate couplers. Tremolo can be obtained in either manual independently of the other manual, since the manuals have independent keying busses.

When the swell-division oscillators are keyed from the great manual they sound with the voices set up for the swell manual, which may be quite different from those selected for the great manual. The same considerations apply when the great oscillators are keyed from the pedal clavier through the great to pedal coupler. However, there is no provision for tremolo to the pedal oscillators since tremolo in the low-frequency range is not desirable. The block diagram in Fig. 5 shows the substantial independence of the swell, great, and pedal organs.

Loudspeakers and Power Amplifiers

The loudspeaker and power amplifier problems associated with this electronic musical instrument are almost unique since substantial amounts of power must be delivered with low distortion at frequencies down to 32 cycles per second. Much less intermodulation can be tolerated in an electronic organ than in more conventional applications. Music that is quite acceptable at low intensity levels will become intolerable at high levels if the usual harmonic distortion is permitted.

The power amplifiers were designed to have harmonic distortion below one percent at full power output. Great care was used in the choice and arrangement of loudspeakers. The manual loudspeakers are provided with diffraction devices that satisfactorily spread the high-frequency components of sound energy through a large horizontal angle. This arrangement avoids the beaming effect that is undesirable in organ music, without the energy loss and time lag that would be associated with diffusion of the high-frequency sounds by bouncing them off the ceiling.

Acknowledgments

Important contributions to the development of this electronic organ were made by Messrs. L. B. Greenleaf, E. L. Kent, S. L. Krauss, R. T. Bozak, S. W. McKellip, J. R. Ford, R. G. Campbell, W. J. Harness, and A. W. Harrison.

Counter Circuits

Basic step-type counter circuit is analyzed to determine design criteria. Its limitations, possible improvements and the relationships between parameters that govern the most stable operation are discussed

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Polarad Electronics
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STEP-TYPE counter circuits are widely used as frequency dividers in the design of television synchronizing generators where stability of division, accuracy of phase and freedom from jitter are of paramount importance. Mention will be made of some artifices for increasing the stability and frequency-division product.

The basic circuit arrangement of the step-type counter is shown in Fig. 1A. It contains a source of periodic pulses (all of equal height) at a frequency f_o, the step-type counter, and a discharge device operating at a frequency f_o/n. The counter circuit shown consists of two capacitors and two diodes.

When a positive pulse is impressed between terminals *A-O*, capacitors C_1 and C_2 are charged through diode V_1. During this interval V_2 is nonconducting. As the charging time constant is usually very small, both capacitors attain the maximum charge in a relatively short time and the impressed voltage, E_p, is divided between the two capacitors in a definite manner. When the individual impressed pulse decreases in voltage from E_p to zero, capacitor C_1 is discharged through the input circuit by means of diode V_2, while C_2 is prevented from losing its acquired charge by the fact that V_1 is nonconducting during this part of the cycle.

A second impressed pulse will deposit an additional increment of charge on C_2. Thus, corresponding to a regular succession of impressed pulses, the voltage across C_2 builds up step-wise and approaches, asymptotically, the value of the impressed voltage E_p, unless interrupted by the discharge device which discharges C_2 completely and causes the process to begin anew.

The manner in which the voltage builds up on capacitor C_2 is shown in Fig. 2 for three values of the ratio C_2/C_1. Curve *A* illustrates the case where the ratio is relatively low resulting in large steps of voltage initially and then smaller incremental changes as the count approaches the desired order of division, in this instance, five to one. Curve *C* illustrates the case where the ratio is relatively high and indicates an almost uniform, but very small, incremental change in capacitor voltage from the first to the n^{th} step. Curve *B* represents the charging curve using optimum parameters, and differs notably from curves *A* and *C* in that the n^{th} or fifth step is much greater than in either of the other cases, and is the maximum value possible.

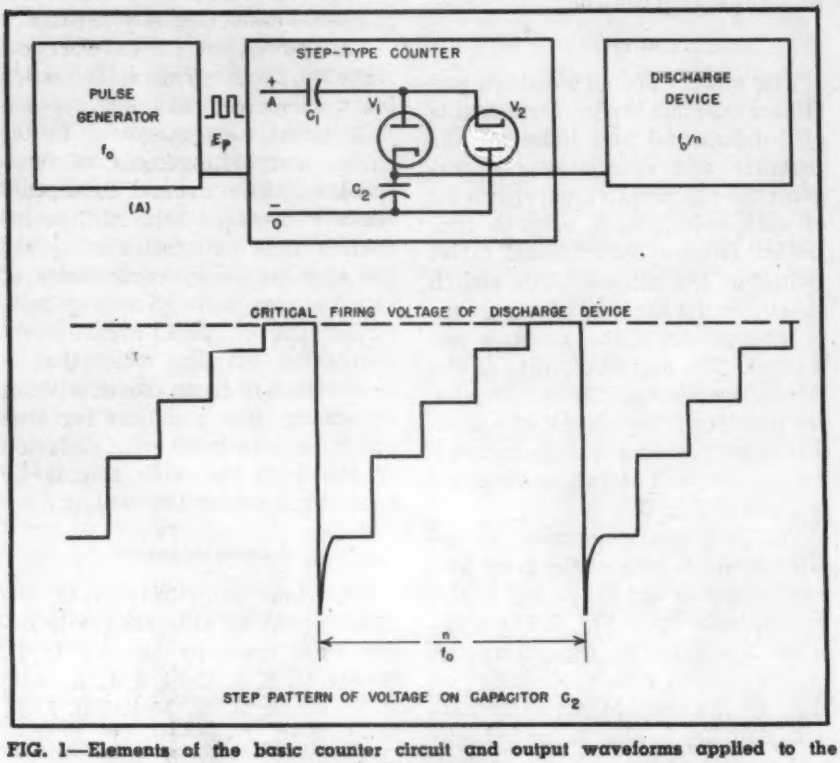


FIG. 1—Elements of the basic counter circuit and output waveforms applied to the discharge circuit.

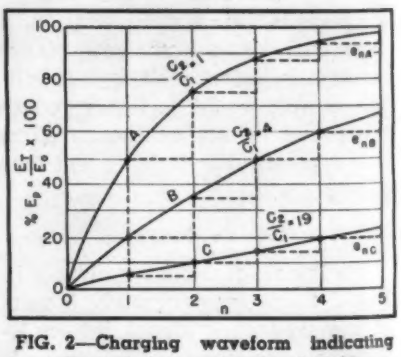
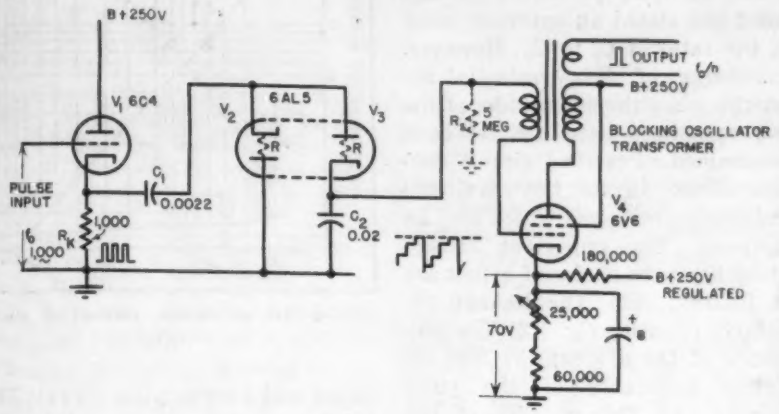


FIG. 2—Charging waveform indicating effect of choice of ratio of C_2/C_1

for Television



PRACTICAL FREQUENCY DIVIDER CIRCUIT

A typical design of the step-type frequency divider presents the following specifications:

Desired division n	= 10
Initial frequency, f_o	= 1,000 cycles per second
Pulse amplitude, E_p	= 100 volts peak
Pulse width	= 100 microseconds
Critical Firing Voltage	= − 10 volts
Shunt Leakage, R_s	= 5 megohms
Effective series resistance (Source plus diodes)	= 1,000 ohms

A suitable circuit is shown above. Tube V_1 is a cathode-follower pulse source, type 6C4.

Tube V_4 is a 6V6 blocking oscillator.

From Eq. 7

$$C_2 = (n-1)\,C_1$$
$$C_2 = 9\,C_1$$

From Eq. 14

$$\text{Minimum } C_2 = \frac{10n}{f_o R_s} = \frac{10 \times 10}{10^3 \times 5 \times 10^6}$$

$$C_2 = 0.02 \text{ microfarad}$$

and $$C_1 = 0.0022 \text{ microfarad}$$

With these values, the height of the tenth step will be 3.9 volts and the value of capacitor C_2 voltage about 63 volts. This requires a negative bias of approximately 70 volts on the discharge tube grid. The bleeder circuit in the cathode of tube V_4 can be adjusted to provide the correct bias.

The charging time constant based on an effective series resistance of 1,000 ohms is approximately 2 microseconds.

From the practical point of view, greatest stability of a step-type counter is attained when the voltage increment corresponding to the n^{th} step of capacitor, C_2, voltage is a maximum. Graphically, this corresponds to the point of maximum slope of the charging envelope at the specified order of division. Thus, in curve B the last increment of voltage is larger than are those of curves A and C. This condition of stability arises from the fact that it is the n^{th} increment of voltage which is utilized to actuate or trigger the following discharge circuits.

The conditions for obtaining the maximum increment, the size of that increment, and the magnitude of the voltage across C_2 when the n^{th} increment is reached, are all of importance when the designer wishes fullest utilization of the step-type counter.

Analysis

In the basic circuit, Fig. 1, the increment of voltage appearing across capacitor C_2 (initially without charge) corresponding to the first of a series of narrow impressed pulses of equal magnitude, is:

$$e_1 = E_p \frac{C_1}{C_1 + C_2} \tag{1a}$$

or $$e_1 = E_p K \tag{1b}$$

where $$K = \frac{C_1}{C_1 + C_2}$$

E_p = magnitude of impressed pulses; e_1, e_2, e_3, . . . = increment of voltage corresponding to first, second, third, . . . pulses.

The second increment of voltage is

$$e_2 = (E_p - e_1)\,K \tag{2a}$$

or

$$e_2 = E_p K\,(1 - K) \tag{2b}$$

The third increment of capacitor voltage is

$$e_3 = [E_p - (e_1 + e_2)]\,K \tag{3a}$$

or $$e_3 = E_p K\,(1-K)^2 \tag{3b}$$

Similarly the n^{th} increment of voltage across C_2, corresponding to the n^{th} pulse is

$$e_n = E_p K\,(1-K)^{n-1} \tag{4}$$

Curves representing Eq. 4 are shown in Fig. 3 for several values of n and clearly indicate the existence of a maximum value of e_n/E_p for each order of division, and that greatest stability may be realized by employing the optimum value of K.

The maximum value of e_n may be determined in the conventional fashion:

$$\frac{de_n}{dK} = \frac{d}{dK}\left[E_p K\,(1-K)^{n-1}\right] = 0 \tag{5}$$

from which is obtained the optimum value of K, that is

$$K = \frac{1}{n} \tag{6}$$

Now since

$$K = \frac{C_1}{C_1 + C_2}$$

Then $$\frac{C_2}{C_1} = (n-1) \tag{7}$$

$$n > 1$$

Substituting the above criterion for maximum into Eq. 4 results in

$$e_{n(max)} = \frac{E_p}{n}\left(\frac{n-1}{n}\right)^{n-1} \tag{8}$$

The total potential E_T to which C_2

is charged at the end of n pulses of impressed voltage is

$$E_T = \sum_{1}^{n} e_n = E_p K [1 + (1 - K) + (1 - K)^2 + (1 - K)^3 \ldots (1 - K)^{n-1}] \quad (9a)$$

From the methods of series summation

$$E_T = E_p [1 - (1 - K)^n] \quad (9b)$$

Equation 9B may be transformed into a more familiar form

$$E_T = E_p \left(1 - \epsilon^{-n \ln \frac{1}{1-K}}\right) \quad (10)$$

Equation 10 is clearly of the same form as the well-known equation for growth of capacitor voltage in a series R-C circuit, that is

$$E_T = E_p (1 - \epsilon^{-\alpha t}) \quad (11)$$

in which t is replaced by n and minus alpha by the natural logarithm of $1/(1\text{-}K)$.

If the criterion for maximum is substituted into Eq. 10, there results

$$E_T = E_p \left[1 - \left(\frac{n-1}{n}\right)^n\right] \quad (12)$$

Examination of Eq. 12 indicates that when optimum conditions are employed, E_T is always less than E_p, in fact

$$0.75\, E_p \geq E_T > 0.636\, E_p \quad (13)$$

The curves in Fig. 4 summarize the relationships derived thus far.

Practical Limitations

The analysis presented to this point has stated an optimum value of the ratio of C_2 to C_1. However, knowledge of this ratio is not enough, since the magnitudes of the two capacitors have not yet been determined. Practical circuit considerations dictate the maximum and minimum values which may be assigned. The important factors which limit the choice of values are as follows: (1) The leakage resistance shunting C_2; (2) The perveance of the diodes; (3) The effective resistance of the pulse source; (4) The stability of the power supply; (5) The stability and resettability of the discharge device; (6) The recovery time of the discharge device; (7) The stability of the pulse source; (8) The highest and lowest frequency of operation; (9) The width of the impressed pulses; (10) The minimum phase shift permissible between input and output pulse; (11) The minimum jitter permissible between input and output pulses.

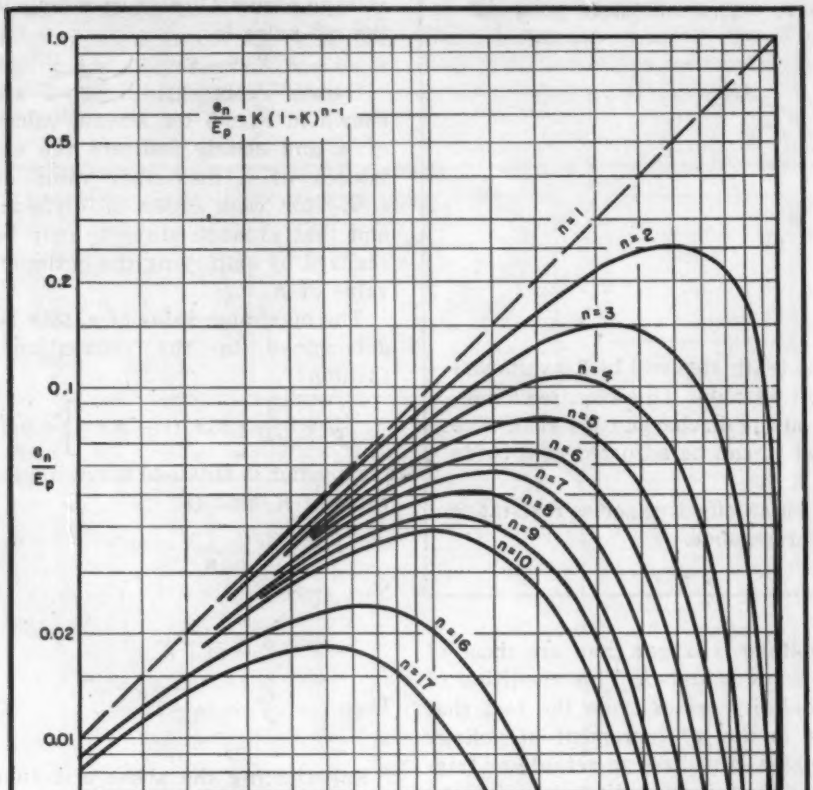


FIG. 3—Curves of various values of n for determining the optimim value of K

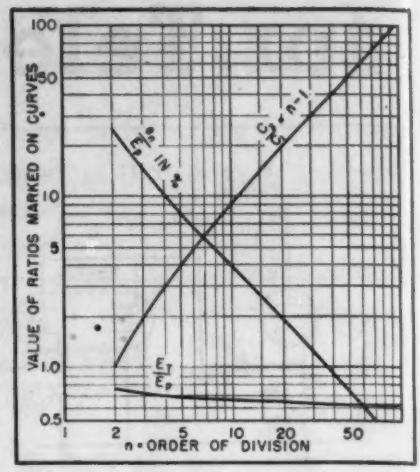


FIG. 4—Set of design curves for diode counters

Every practical circuit has intimately associated with it leakages, which in this case may be represented as a definite resistance R_1 shunting the storage capacitor C_2. The effect of R_1 is to partially discharge C_2 in the time between successive steps. If the frequency $f_o/_n$ is low, C_2 must, of necessity, be made large, so that the shunt discharge time constant, R_1C_2, will be sufficient to maintain the charge on C_2. The appearance of the step wave form with a short time constant is shown in Fig. 5. A good rule of thumb is to make C_2 sufficiently large, so that the discharge time constant, R_1C_2, is at least ten times the period of the lowest operating frequency. That is

$$R_1C_2 \geq 10 \frac{n}{f_o} \text{ seconds} \quad (14)$$

It was assumed in the earlier analysis that the time for C_2 to acquire an increment of charge is negligibly small. Actually, this may not always be the case, as the series resistance of the pulse source and the perveance of the diodes will slow up the rise time appreciably. Figure 6 shows the wave form during the charging interval at the n^{th} increment.

The finite rise time has two undesirable effects. It prevents the increment of charge from ever reaching the value predicted by Eq. 8 during the charging interval, especially if narrow pulses are used. This effect reduces the ap-

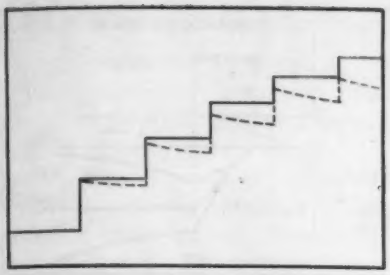


FIG. 5—The solid line represents the normal charging waveform and the dashed line shows the effect of shunt leakage across C_2

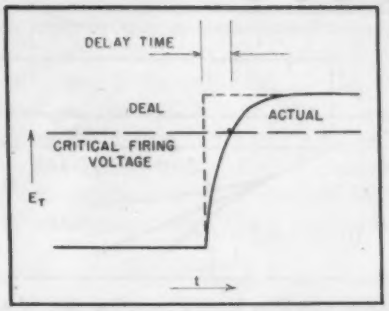


FIG. 6—Effect of finite rise time in producing delays between initiating pulses and output pulses. Small changes in pulse height or of critical firing voltage will cause changes in delay time, causing jitter in the output pulses

parent pulse voltage by some definite amount and thereby makes the frequency division somewhat dependent on pulse width and operating frequency. A satisfactory design rule which produces a negligible loss in voltage because of charging time constant is to make the series time constant less than ten percent of the pulse width.

A more important difficulty introduced by the finite rise time is the irreducible phase delay. Phase delay, in itself, may not be objectionable in many designs, but what is troublesome is the jitter resulting from minute fluctuations in pulse height and power supply variations. The net effect is to cause slight shifts in the time of firing of the discharge device. The series charging time constant of the R-C circuit, made up of the source resistance, diode resistance, C_1, and C_2 should be very small. This requirement dictates the use of high-perveance diodes, low-impedance pulse sources and minimum values of C_1 and C_2.

Earlier in this discussion it was stated that periodically capacitor C_1 was discharged by means of diode V_2 through the pulse generator impedance. Consideration of the time intervals involved as well as the circuit constants shows that this statement is only approximately correct. It takes an infinite time to discharge C_1 completely; a finite time to reduce the voltage across C_1 to some predetermined value. The effect of this residual charge is to oppose the pulse voltage which is trying to produce voltage increments on C_2. This effect becomes more pronounced as the pulse width is increased or as the pulse repetition frequency is raised; that is, as the duty cycle is made larger. The cumulative result is to make the stability of division dependent upon frequency and pulse duty cycle. To minimize this phenomenon, C_1 should be chosen as small as possible and the circuit resistance held down.

The recovery time of the discharge circuit places an upper limit on the frequency of operation; but many suitable discharge circuits are known to the art, so that a suitable one can be selected for the particular frequency range.

It has been shown that low-frequency considerations dictate large values of the counter circuit capacitances, whereas high-frequency work requires just the opposite. Evidently, the designer must reconcile the conflicting requirements and effect a suitable compromise.

Conclusions

Having achieved the optimum choice of circuit parameters, the maximum order of frequency division which may be attained with good stability depends upon the amplitude of the n^{th} increment of voltage on capacitor C_2 and on the nature of the discharge device. The previous analysis has shown that as the magnitude of n is increased, the size of the step decreases to the point where the discharge device may trigger erratically because of noise, line voltage fluctuation, or power supply ripple. Thus, the size of the n^{th} step must be sufficiently large to make negligible these inevitable disturbances. Some allowance must also be made for ageing of the circuits which may change the operation and critical firing voltage of the discharge device.

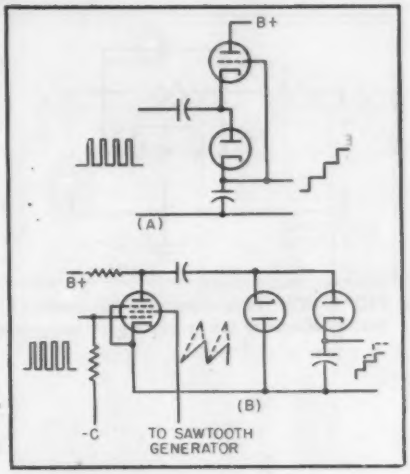


FIG. 7—Two proposed circuits for improving counter stability. Shown at *A* is the Hallmark system using a triode for linearization of the staircase charging curve. In circuit *B*, a sawtooth waveform on the screen grid of a pentode driver tube causes the transconductance of the tube to rise with time, and cause heights of steps to increase instead of decrease. By proper selection of waveform of screen grid voltage, any type of charging characteristic may be obtained

The curves in Fig. 2 show that the envelope of the charging curve of capacitor C_2 voltage is an exponential function of the form

$$y = K\,(1 - \epsilon^{-\alpha t})$$

where K and α are constants. One of the inevitable characteristics of such a function is that successive increments of y must become progressively smaller as time elapses. As shown for a count of ten to one the size of the n^{th} step cannot exceed approximately 3.9 percent of the impressed pulse voltage. To improve the stability of counter performance, some means for making the tenth step larger than 3.9 percent of E_p is needed. Graphically, the envelope of the charging curve must be made less concave downward, perhaps more closely linear, or best of all, concave upward. At the same time, the charging curve should attain the same or even greater value at the end of n steps than does the normal curve.

Several methods are known for accomplishing the desired distortion of the charging curve. Figure 7 shows some of the possible methods. In a particular design, the availability of auxiliary pulses and waves will suggest other methods of approach.

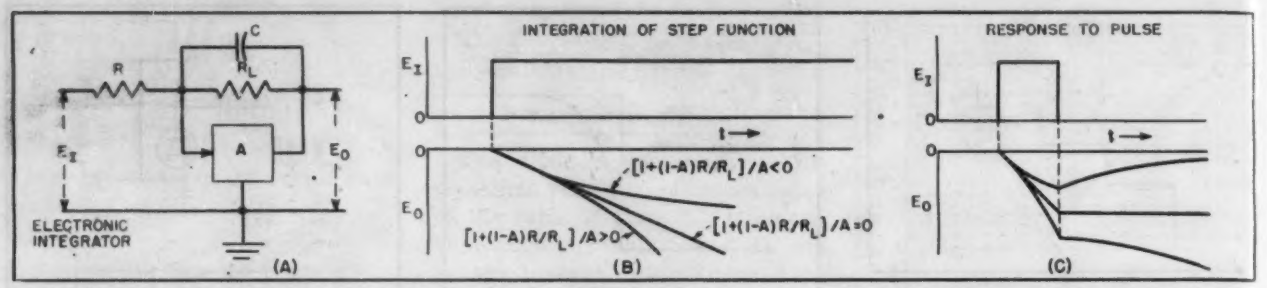


FIG. 1—The basic electronic integrator (A) uses an amplifier having negative gain. If an amplifier having positive gain is used, the factor affecting the accuracy of integration can be made zero (B) giving exact integration holding its output from a pulse (C)

Design of D-C Electronic Integrators

Effects on the accuracy of integration of amplifier gain, capacitor leakage, input and output resistance are analysed. A compensated circuit capable of exact integration is developed

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INTEGRATORS, as was pointed out in a previous article, are the most critical components of d-c analog computers. These circuits are also useful in instrumentation, especially for determining averages. Hence the analysis and design of high-performance integrators and the circuits directly associated with them are important to engineers.

Basic R-C Integrator

The d-c integrator of Fig. 1A is at present the most commonly used type. It consists of an integrating network comprising resistance R and capacitance C in conjunction with a d-c amplifier of gain A. Because the leakage resistance R_L of the integrating capacitor constitutes an additional feedback path across the amplifier, it must also be taken into consideration. The problem is to adjust the design factors to make the output voltage E_o of the integrator as nearly proportional to the time integral E_I/p of the input voltage E_I as is possible.

In the circuit of Fig. 1A, the current through R must equal the sum of the currents through R_L and C, exclusive of currents circulating through the amplifier. Thus the nodal equation for the integrator is

$$E_o\,(1 - 1/A)\,(Cp + 1/R_L) = -\,(E_I - E_o/A)/R \qquad (1)$$

so that

$$E_o = \frac{AE_I}{(1-A)RCp - 1 + (1-A)R/R_L} \qquad (2)$$

The action expressed by Eq. 2 approximates true integration if

$$[1 + (1 - A)R/R_L]/A \to 0 \qquad (3)$$

which can be achieved in practice by making the gain A large (10^4 to 10^5) and by using capacitors with as low leakage as possible. In the ideal case $R_L = \infty$ and Eq. 2 reduces to the simplified formula given in the previous article. In the event that A is very large, Eq. 2 simplifies to

$$E_o \approx \frac{A}{1-A}\frac{1}{RCp}E_I \approx \frac{E_I}{RCp} \qquad (4)$$

indicating that the circuit performs true integration.

In general, the integration will be in error due to finite gain and leakage. A quantitative estimate of the quality of integration can be found by applying Eq. 2 to a step function input for which

$$E_I = 1(t) = 0 \text{ for } t < 0 \\ = 1 \text{ for } t > 0 \qquad (5)$$

so that the step response is

$$E_o(t) = -\left\{\frac{A}{A-1}\frac{t}{RC} + \frac{A[1+(1-A)R/R_L]}{(A-1)^2}\frac{t^2}{2(RC)^2} + \ldots\right\} \qquad (6)$$

where the first term of the series is the integral term (compare with Eq. 4), and the second term is the significant error term. Fig. 1B is a graph of the step response showing the effect of the error. The respective curves for positive or negative values of

$$[1 + (1 - A)R/R_L]/A$$

differ appreciably only for large values of the computing time t. If the above factor is negative, the error is somewhat smaller being in fact smaller than the first error term in Eq. 6. This condition will be assumed henceforth.

The percentage error due to finite gain and leakage is, therefore

$$\frac{[1 + (1 - AR/R_L]t}{2RC(A-1)} \leqq \frac{P}{100} \qquad (7)$$

so that if $E_o\ (t)$ is to be within P percent of the integral term (Eq. 4), it is necessary that

$$t_{MAX} \leqq \frac{PRC}{50}\,\frac{A-1}{[1 + (1-A)R/R_L]} \qquad (8)$$

Because the networks are linear,

This article is based on Report 5256-2061, Electronic Solution of Differential Equations, prepared by the author while with Sperry Gyroscope Co., Great Neck, N. Y. The author is grateful to Sperry and in particular to W. L. Barrow, Chief Engineer, for making publication possible. Due to classification of much associated material, it is regretfully impossible to credit individuals and organizations with earlier work on d-c analog computers.

this criterion applies to any input.

Compensated Integrator

The electronic integrator discussed so far gives only an approximation to integration, an approximation that is made better as the amplifier gain and leakage resistance are made higher. Usually the gain used in d-c integrators is negative. In this case, the effect of leakage can be interpreted as degenerative feedback which decreases the effective gain of the integrating amplifier. The foregoing analysis shows that leakage can seriously reduce the quality of integration even with amplifiers of extremely high gain.

If the amplifier gain is made positive, the capacitor leakage constitutes regenerative feedback. By choice of A and R_L make

$$[1 + (1 - A)R/R_L] = 0 \qquad (9)$$

in which case such a compensated integrator performs accurately even for small A, as shown by substituting Eq. 9 into Eq. 2. The compensation (Eq. 9) constitutes a striking means for overcoming the effects of finite amplifier gain and capacitor leakage.

It is important to note (Eq. 2) that the compensated amplifier need not be unstable despite the regeneration, because the latter is counteracted by degenerative feedback through C. The seemingly unstable case of $p = 0$ has no practical meaning because to investigate the effect of zero frequency would require an infinite computing time.

Figure 1C shows the integration of a square pulse for various

$$[1 + (1 - A)R/R_L]/A$$

and indicates how the compensated integrator holds the output after the pulse has passed. Unavoidable changes in gain and leakage make it impossible to maintain Eq. 9 indefinitely and thus achieve perfect compensation. Nevertheless, considerable improvement in integrator performance is obtained even by approximate compensation. For estimating error, it is only necessary to know within what limits A and R_L may vary during computation; Eq. 7 now applies only to the most unfavorable combination of A and R_L.

Changes of amplifier gain A will alter the proportionality factor $A/(1 - A)$ of Eq. 4 and, in the case of the compensated integrator, will disturb the compensation (Eq. 9). Differentiation of Eq. 6 with respect to A will give a detailed indication of the error caused by changes in gain. Thus a change in the gain A of ϵ A percent will cause a percentage error less than

$$\frac{\Delta_A}{A-1}\left\{1 + \frac{t}{2RC}\left[\frac{A+1}{A-1} - \frac{R}{R_L}\right]\right\}$$

where, as before

$$[1 + (1 - A)R/R_L]/A < 0$$

Changes in leakage such as those due to atmospheric moisture have a similar effect. However, in the usual case of large R_L the change may be so large that the errors have to be estimated from Eq. 7. In any case, errors due to changes in gain and leakage are minimized by making A large.

Distortion and Drift

An amplitude distortion may be interpreted as due to a change in gain occurring over certain portions of the signal. The error incurred in integrating a simple step function due to a percentage of distortion can thus be estimated from the same relation that applies to error from changes of gain. Likewise, error due to distortion can be minimized by making the amplifier gain high. It is also necessary to operate the output tube well within its linear range.

In d-c analog computers, the output of each amplifier is balanced to zero before computation so that, in the ideal case, only the desired signal voltages are applied to the integrators. Actually stray voltages due to noise, unbalances, grid current and drift occur during computation and they are integrated, leading to errors in the output. A single noise pulse will be integrated as in Fig. 1C, but high-frequency random noise will tend to cancel itself. Integrators of the d-c type are fairly susceptible to interference from power line frequencies, which should be kept out of the equipment by shielding and placement of components.

A steady unbalance voltage due to grid current or undirectional drift at the input of an isolated integrator introduces an absolute error approximately equal to $E_D At/(A - 1)RC$ where E_D is the drift voltage. To minimize such error it may be expedient to balance each

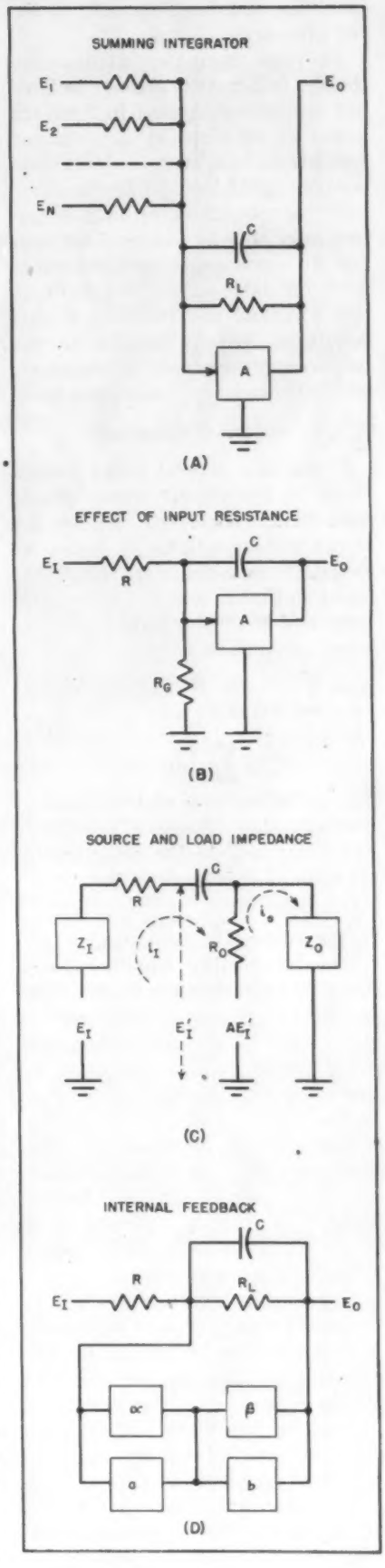

FIG. 2—All components must be considered in analysing integrators

amplifier, not for zero output, but for zero drift.

In most computer applications the d-c integrators are not isolated but are interconnected in feedback loops to simulate stable, damped oscillations. In such systems temporary unbalance tends to damp out; the amplifiers in such a system need only be balanced for output at some convenient reference level for zero output and the system will tend to settle back to this condition. Steady inputs or unbalances, after an initial transient, will only change the reference level.

Additional Resistances

There are several other resistances in the circuit whose effects need to be considered. Figure 2A shows the intentional inclusion of several resistances in the integrator input so that it will add several inputs and multiply each by a constant, giving an output

$$E_o = \sum \frac{E_k}{R_k} \frac{A}{(1-A)Cp + \frac{1-A}{R_L} + \sum \frac{1}{R_k}}$$

$$\approx \frac{A}{1-A} \sum \frac{E_k}{R_k Cp} \qquad (10)$$

The error analysis and methods of compensation discussed previously can be applied to the summing integrator if R is replaced by

$$[\Sigma(1/R_k)]^{-1}$$

in the respective formulas.

The integrating amplifier has a finite input resistance R_o as shown in Fig. 2B; it may be considered as a grounded input terminal in a summing amplifier. The results of the preceding considerations show that, so far as the quality of integration is concerned, R_o decreases the effective value of R as if R_o were connected in parallel with it. Accordingly, it is desirable to make R_o as large as possible and to use a cathode-follower input.

In general, the integrator will be connected to a source of impedance Z_I and a load of impedance Z_o. The output impedance of the amplifier R_o is effectively the resistance formed by the plate and load resistances of the output stage in parallel. When Z_I and Z_o are resistive the equivalent circuit Fig. 2C shows that the approximate effect of the impedance ratio R_o/Z_o is to reduce the effective amplifier gain in the ratio $1/(1 + R_o/Z_o)$ if the absolute magnitudes of AR and AZ_o are both much greater than R_o, while Z_I contributes to the time constant of the integrator and may have to be considered when calibrating it.

Usually the input and output of the integrator will be connected to similar integrators or to summing amplifiers. In such systems R_o is 20 to 50 kilohms and R is of the order of 5 megohms, so that presumably the effects of Z_I and Z_o are small. However, because of the complex feedback paths in computers, it may be necessary to solve the very complex network equation for the complete computer to gain exact information on its performance. The possibility of neglecting the output impedance of one integrator as compared to the input impedance of the one following it has great practical importance; it enables one to compute the transfer functions of cascaded integrators by simply multiplying the transfer functions of individual integrators.

In calibrating the integrator, Eq. 4 may be taken as the transfer function. The value of $A/(1-A)RC$ is found by actually measuring the output-input ratio (at 60 cps with a calibrated potentiometer). Errors in measurement and slight changes in R and C make the calibration accurate within about 0.5 percent; the effect of A has been discussed above. For large A, Eq. 4 may be approximated by $-1/RCp$, where R and C can be found by accurate bridge measurement.

Optimum Conditions

Whether the integrator is compensated or not, most of the errors are reduced by decreasing t/ARC and $1/R_L$, which means using short computing times, high gain, high leakage and long integrator time constant. Even in the compensated integrators, high gain is useful to reduce errors from distortion and gain changes. High gain or compensation and feedback can make errors from finite gain, gain changes and distortion very small.

The most serious errors, those that are difficult to minimize, are drift due to unbalances and changes in leakage resistance. Drift errors can be minimized by careful balancing (for zero drift) and stable amplifiers and power supplies. Reduction of t/RC may also help, but is limited by scale factor. Reducing the computing time reduces most of the errors, but it is limited by the frequency response of recorders and associated servos.

Feedback in the integrating amplifier can (1) decrease amplifier distortion and instability if it is degenerative, or (2) increase the gain if it is regenerative. However, if feedback over the entire amplifier is used, the accuracy of integration will be unaffected because the improvements in the amplifier will be offset by impairments in the integrator due to reduced gain. Nevertheless, degeneration is advantageous because by it the amplifier gain of a compensated integrator can be reduced without increasing instability and distortion, and a low leakage resistance can be used (Eq. 9). The possibility of connecting a stable resistor across the capacitor affords a means of decreasing changes in R_L due to humidity.

Even more interesting results can be obtained if feedback is used around portions of the amplifier. In a two-stage amplifier having an overall gain A and the stage parameters shown in Fig. 2D.

$$A = \frac{ab}{(1-a\alpha)(1-b\beta)} \qquad (11A)$$

$$\Delta A, B = \frac{\Delta a}{1-a\alpha} + \frac{\Delta b}{1-b\beta} \qquad (11B)$$

$$\Delta A, B = \frac{\Delta D_a}{1-a\alpha} + \frac{\Delta D_b}{1-b\beta} \qquad (11C)$$

where ΔA, Δa, and Δb are the percentage gain changes, and ΔD, ΔD_a, and ΔD_b are the distortion percentages. Feedback around the individual stages thus makes it possible to greatly reduce effect of gain changes and distortion in the power stage by using nearly critical regeneration on the voltage stage, as well as high gain in both stages. Similarly the effects of gain changes and distortion in the voltage stage can be made small by nearly critical regeneration on the power stage, although this will usually be unnecessary. The very high gain resulting from the regeneration can be reduced by overall degeneration. The feedback networks should be arranged so as not to decrease the input resistance of the amplifier.

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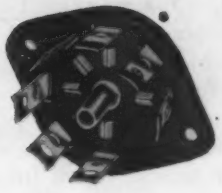

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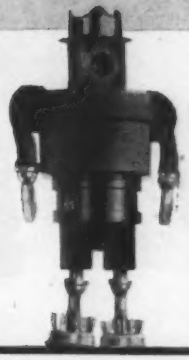

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TUBES AT WORK

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Edited by VIN ZELUFF

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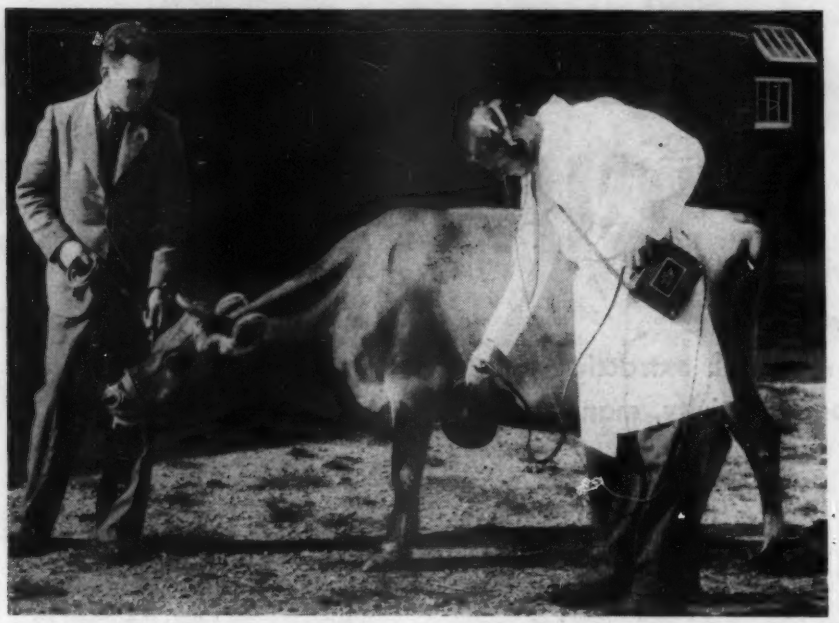
Metal Detector for Cows

Being coarse feeders, cows are prone to swallow small pieces of wire or other metal, with possibly serious results. When this is suspected, the use of a Cintel metal detector made in Britain enables a diagnosis to be made accurately and quickly. As a result, many veterinary surgeons are now regular users of the instrument.

The detector can also locate to within an inch or two, pipes buried up to 2 feet, 9 inches below ground and will detect small pieces of metal embedded in timber or other materials to a depth of 9 inches.

If used in conjunction with an oscillator, the instrument will detect such things as pipes and cables buried up to 30 feet below ground but exposed at one point. It can also follow pipes for long distances and a six-inch pipe buried three feet can easily be traced up to 300 yards on each side of the point where the oscillator is connected.



Metal detectors offer a means of diagnosis for sick cows who swallow stray bits of metal with deleterious effects

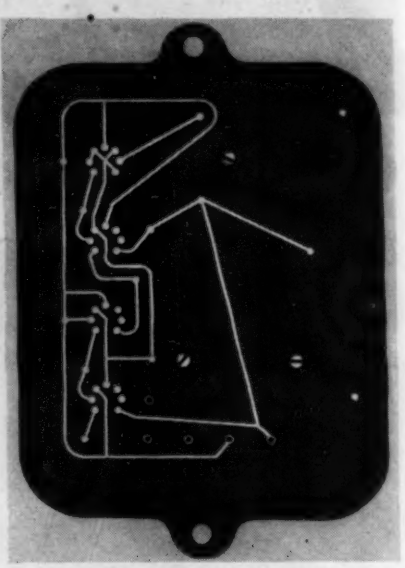
Sprayed Wiring for Control Amplifier

By RALPH T. SQUIER

Assistant Director of Research
Minneapolis-Honeywell Regulator Co.
Minneapolis, Minn.

INVESTIGATING new means of mechanizing electrical wiring has resulted in development of several techniques that can be applied to manufacture of electronic control units. The illustrations show one of these, an experimental amplifier with sprayed copper leads in grooves on a plastic base.

Grooves were made in the base, first by milling and later by molding, into which the metal was sprayed. It was found that the metal impinging upon the lands between the grooves could be easily wiped off. There were, however, some problems that immediately presented themselves concerning spacing, width, depth, bottom surface, and shape of the groove.



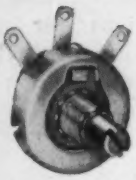
Sprayed wiring on the plastic base of the amplifier. Terminals and wiring of the miniature sockets show clearly at left

Certain minimum separations between leads must be maintained in electronic circuits to eliminate electrical leakage. Using a groove width of $\frac{1}{8}$ inch, even with miniature tubes having closely-spaced pins, resulting separations were within these limits. This groove width is more or less arbitrary, being wide enough to allow ample room for spraying to the bottom of the groove and to provide sufficiently high conductivity while leaving adequate spacing between leads.

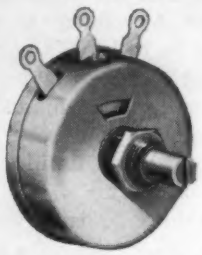
A series of tests was conducted to determine optimum groove depth for adhesion of the copper to the base. This depth seems to be critical and should be maintained at 0.040 ± 0.005 inch.

Measurements made on the bonding of the copper to the bottom of a molded plastic groove show conclusively that some sort of rough-

ONLY SO BIG...



TYPE C—*Only 1 1/32" in diameter. Full two watts normal rating (entire element) for continuous operation.*



TYPE M — *Normal rating of 4 watts. Diameter 1 7/8". Insulated for 1,000 volt DC breakdown to ground.*

TYPE E—*Dissipates 7 watts. Diameter 2 5/16". Supplied with grounded contact arm.*

. . . they have everything you want in a wire-wound control!

Size is always an important matter when you're designing products like radio and television receivers, testing equipment, light dimming devices and miniature motor controls. That's why Mallory makes its wire-wound variable resistors good *and small*—the type C control being the smallest two-watt control of its kind available today.

On the plus side, too, is the fact that all Mallory wire-wound controls are designed for maximum heat dissipation. In addition, the M and E types are metal-enclosed to provide electrostatic shielding . . . all types are tapered with extreme accuracy (linear taper tolerance is within 3%) . . . precision-wound to give extremely long, noise-free service. A special feature of the M and C type controls is a spring clamp which maintains positive pressure between silver-plated terminals and silver element terminations, insuring extremely low terminal resistance.

The M type Variable Resistor is also available in a complete line of Mallory T and L Pad Attenuators, designed to provide impedance matching in audio circuits or resistive networks to secure maximum power transfer and minimum distortion.

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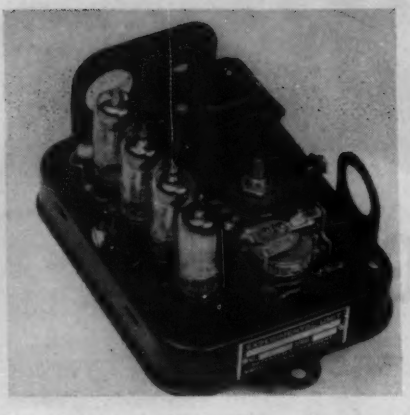
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

ening is desirable. Longitudinal and diagonal ridges gave much better results than a smooth surface. To determine the bonding of the copper to the panel, a small circular hole of the same width as the groove was drilled through the panel prior to spraying. A steel pin was inserted through this hole flush with the bottom of the groove. After spraying, this pin was removed and one of slightly smaller diameter inserted in the hole and the force required to dislodge the copper conductor was measured. The average of these forces for smooth grooves was 100 grams and for roughened grooves, 600 grams. The groove must have a sharp edge at its top so that the copper lead is automatically severed from the lands at the time of deposit.



Top view of control amplifier with sprayed wiring

After spraying, the plastic and copper are painted with a mixture of Durez and varnish that further improves the bonding of the copper to the plastic.

Sprayed copper leads in grooves on a plastic base were subjected to the following conditions without detectable change in electrical or physical characteristics:

1. Temperature variation in 10 cycles from −65 F to +160 F.
2. Pressure variation from normal atmospheric to that prevailing at 50,000 feet.
3. Vibration in a 0.020-inch diameter circle inclined at 45 degrees for one hour each at 10, 30, and 50 cycles per second.

The amplifiers constructed have been subjected to all the conditions noted above and to extremes of humidity. They have operated under moderate conditions for months with no change whatever that could be attributed to deterioration of the sprayed copper leads.

Beat Frequency Tone Generator with R-C Tuning

By J. W. Whitehead
Central High School
Leeds, England

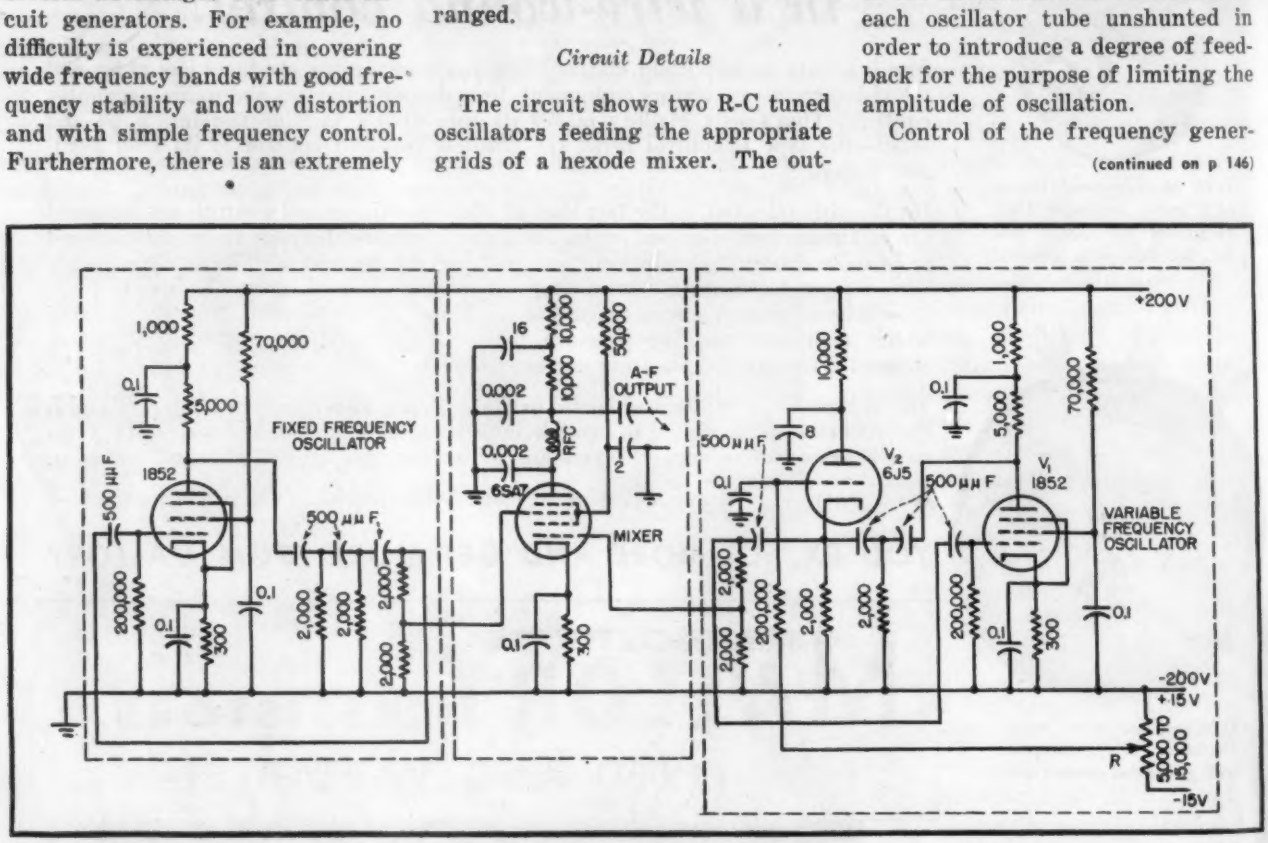
THE PRINCIPLES of resistance-capacitance tuning of oscillators may easily be adapted to the design of tone generators using the heterodyne technique. Such a circuit has several advantages over tuned-circuit generators. For example, no difficulty is experienced in covering wide frequency bands with good frequency stability and low distortion and with simple frequency control. Furthermore, there is an extremely low degree of coupling with neighboring components. Remote control of frequency can also be arranged.

Circuit Details

The circuit shows two R-C tuned oscillators feeding the appropriate grids of a hexode mixer. The output from each oscillator is obtained by a suitable tap on the final resistance of each of the phase-shifting networks. A refinement (not shown) would be to leave a portion of the automatic bias resistance to each oscillator tube unshunted in order to introduce a degree of feedback for the purpose of limiting the amplitude of oscillation.

Control of the frequency gener-

(continued on p 146)



The values shown in the diagram provide oscillator frequencies of about 92 kc and the resulting beat-frequency variation is from a few cycles to over 20 kc. A voltage-regulated plate supply is preferable

with non-fraying DIEFLEX

You can eliminate many assembly problems if you specify a varnished tubing that does not fray during assembly operations. Fraying not only slows production but is a source of electrical trouble. Dieflex varnished tubing products are noted for their ability to be cut evenly and cleanly, to return to roundness after cutting, and to withstand handling and the rough usage of product assembly without back-raveling or fraying. They save you assembly time and cut your costs because you won't need to do the same job twice.

Dieflex varnished tubings and saturated sleevings of finely braided cotton or inorganic glass fiber have this non-fraying characteristic in all grades and sizes. In addition, all Dieflex products have extreme flexibility, high dielectric strength, smooth inside bore, excellent push-back quality, and many other superior features. You can't go wrong when you specify Dieflex on every job.

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VTA Grades C-1 and C-2 Heavily Coated Saturated Sleevings
VTA Grade C-3 Lightly Coated Saturated Sleevings
Heavy Wall Varnished Tubings and Saturated Sleevings

MADE WITH BRAIDED GLASS SLEEVING BASE

VTA Grade A-1 Magneto Grade Varnished Fiberglas Tubings
VTA Grade C-1 Extra Heavily Saturated Fiberglas Sleevings
VTA Grade C-2 Heavily Saturated Fiberglas Sleevings
VTA Grade C-3 Lightly Saturated Fiberglas Sleevings
Silicone-Treated Fiberglas Varnished Tubings and Sleevings

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THE ELECTRON ART

Edited by FRANK ROCKETT

An Image Storage Tube 132
Extending Linear Range of Reactance Modulators 134
Characteristics of Some Oil Impregnated Capacitors 168
End Resistance Materials 172
Null Temperature Bridge 180
Survey of New Techniques 186

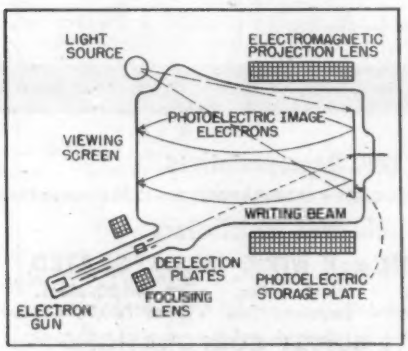
An Image Storage Tube

LONG-TERM OBSERVATION (up to three weeks) of events occurring in 10^{-6} seconds is made possible by the Krawinkel storage tube, which was developed in Germany. The tube is the embodiment of a new technique that, after further research and development, makes possible retention of images for detailed evaluation that are conventionally produced on cathode-ray tubes. The storage tube is therefore applicable wherever the cathode-ray tube is used. For example, the indicator of a search radar set may show only a few widely separated spots along the trajectory of a missile. To recognize that these indications all relate to the same moving target, and to determine its position of origin, the screen image needs to be stored long enough for the controller to study it.

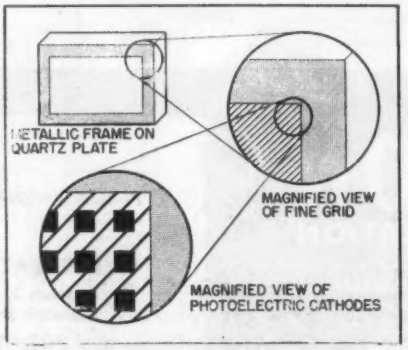
Characteristics of Storage Tube

This image storage tube, at its present stage of development, has electrostatic deflection with magnetic focusing of the 0.2 to 0.3-millimeter diameter writing beam, and magneto-optical projection of the stored image onto the viewing screen. Writing and erasing speed is 20,000 meters per second. The storage time, with the image illuminated for observation, is 15 minutes; with it unilluminated it is three weeks. The image can be erased intentionally at any time. The stored elements are 0.0036 square millimeters in area.

The image is electrically stored in small capacitors. The foundation for the storage surface is a photosensitive layer. On this base are small insulated islands which act as capacitors, one plate being the common photosensitive base, the other being the surface of the insulation. Each capacitance is about 0.002 $\mu\mu$f, and will retain a charge of 5×10^{-14} coulomb for the three weeks. Using secondary emission of the insulated islands, either a positive or a negative charge relative to the photosensitive cathode, depending on the velocity of the cathode-ray electrons, is painted on the island capacitors to form the stored image. When the image is to be viewed, the storage surface is illuminated by invisible light, from outside the tube. Thus electrons are emitted photoelectrically from the cathode in proportion to the positiveness of the charges on the adjacent capacitors, and are projected to a fluorescent viewing screen to reproduce the image.



Operation of image storage tube



Construction of storage plate

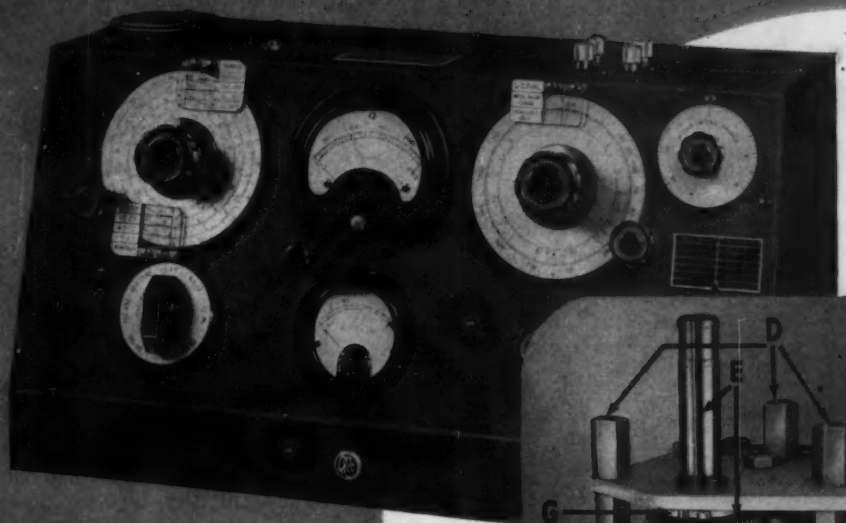
Constructional Features

Although the foregoing description of insulated islands on a photocathode explains the action of the storage plate, the plate is made by depositing photosensitive islands on a fused quartz plate. First a narrow metallic frame is evaporated around the edge of the insulating quartz plate. Then a grid of very fine conducting lines is evaporated onto the surface. Last a great number of photoelectric cells are evaporated through holes of a fine mesh net. Thus, each photocell contacts at least one line of the grid so that all the photocells are connected together and to the metallic border. The small uncoated areas of the quartz plate constitute the capacitors.

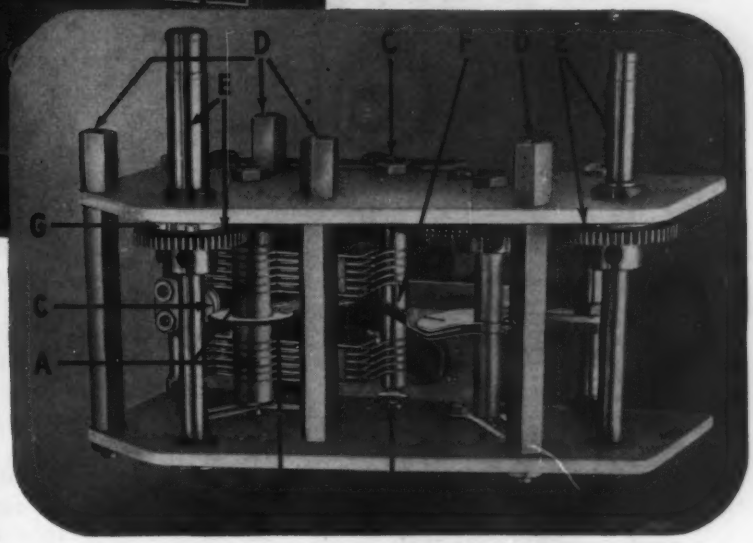
Getter is an auxiliary triode

To prevent leakage of the charges from the capacitors, a very high vacuum of 5×10^{-7} millimeters of mercury is maintained inside the tube. To do this, a getter tube is incorporated inside the storage tube. The getter tube is a triode, the plate of which has a surface of getter material. The grid is made positive, the plate negative. Electrons from the thermal cathode positively ionize the gas molecules in the getter tube. The ions are then actively attracted to the getter material to assure their removal from the storage tube (An Image

For the MEASUREMENT of
Q, INDUCTANCE and CAPACITANCE



The
160-A Q-METER
50 KC. to 75 MC.



Radio frequency circuit design often requires the accurate measurement of Q, inductance, and capacitance values. For this application, the 160-A Q-Meter has become the universal choice of radio and electronic engineers throughout the country.

Each component part and assembly used in the manufacture of this instrument is designed with the utmost care and exactness. Circuit tolerances are held to values attainable only in custom built instruments.

Consider, for example, the Q tuning capacitor assembly of the 160-A Q-Meter, specially manufactured for maximum range, low loss, and minimum residual inductance. The ultimate design of this unit was reached only after months of intensive engineering research to produce the finest in performance, quality, and workmanship.

This is but one of the many desirable features of the 160-A Q-Meter which contribute to its outstanding accuracy and dependability.

Be sure to include the 160-A Q-Meter in your new equipment plans for 1948.

Write for Catalog "E"

Shown above is the Q tuning capacitator assembly of the 160-A Q-Meter. Note the following design features of this unit—features which insure reliable, trouble-free operation.

A. Parallel connection of dual rotor and stator assemblies minimizes internal inductance and resistance.
B. Spring silver fingers contact both sides of silver disc to provide low series resistance.
C. Three point pyrex ball stator suspension reduces losses and permits accurate stator alignment.
D. Four point panel mounting designed to produce maximum structural rigidity and capacitance stability.
E. Precision-cut brass spur gears and stainless steel shafts, mounted in oversize bearings, assure long, trouble-free service.
F. Common stator mounting for main and vernier stator plates reduces loss and internal series resistance of vernier capacitor section.
G. Positive shaft stop protects main rotor assembly and gears against mechanical overload.

SPECIFICATIONS

Oscillator Frequency Range: 50 kc. to 75 mc. in 8 ranges.
Oscillator Frequency Accuracy: ±1%, 50 kc.—50 mc.
±3%, 50 mc.—75 mc.

Q Measurement Range: Directly calibrated in Q, 20-250. "Multiply—Q—By" Meter calibrated at intervals from x1 to x2, and also at x2.5, extending Q range to 625.

Q Measurement Accuracy: Approximately 5% for direct reading measurement, for frequencies up to 30 mc. Accuracy less at higher frequencies.

Capacitance Calibration Range: Main capacitor section 30-450 mmf, accuracy 1% or 1 mmf whichever is greater. Vernier capacitor section +3 mmf, zero,—3 mmf, calibrated in 0.1 mmf steps. Accuracy ±0.1 mmf.

BOONTON RADIO Corporation
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DESIGNERS AND MANUFACTURERS OF THE Q METER · QX CHECKER · FREQUENCY MODULATED SIGNAL GENERATOR · BEAT FREQUENCY GENERATOR AND OTHER DIRECT READING INSTRUMENTS

Storage Tube, Applications and Suggested Research Program, *Air Technical Intelligence. Tech. Data Digest*, p 11 July 1, 1947).

Extending Linear Range of Reactance Modulators

By FRITZ BRUNNER
Dipl. Electr. Engr.
Swiss Federal Inst. of Tech.
Muttenz, Baselland, Switzerland

LARGE FREQUENCY DEVIATION can be obtained directly from a frequency modulated oscillator by interposing a stage of amplification between the oscillator tank and the grid of the reactance tube.

Principle of Operation

In the basic reactance tube frequency modulated oscillator, a variable reactive current I_R whose magnitude is controlled by the modulating signal is supplied through a reactance tube to the tank circuit. The oscillator tube supplies a constant in-phase current I_P to the tank circuit as shown in Fig. 1. Under these conditions the instantaneous frequency is

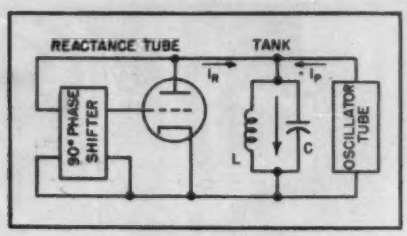


FIG. 1—Basic reactance modulators

$$f = \frac{1}{2\pi[L(C + I_R/2\pi fE)]^{1/2}}$$

where L is the inductance of the tank, C is its capacitance, and E is the voltage across it. If the resonant frequency of the tank circuit is

$$f_0 = 1/2\pi(LC)^{1/2}$$

the deviation frequency approximates

$$\Delta f = f - f_0 \approx -I_R/4\pi EC$$

which shows that the extent of the deviation is directly proportional to the reactive current supplied by the reactance tube.

In conventional reactance tube f-m oscillators I_R is obtained by shifting the phase of the tank circuit voltage as near as possible to 90 degrees by a resistance-reactance circuit, and using this voltage to control the reactance tube. Unfortunately considerable attenuation is associated with the phase-shifting network, so that the I_R available from the reactance tube is small in comparison to the voltage across the tank circuit. The frequency deviation that can be produced, especially at vhf, despite the greatest possible L/C of the tank circuit, is small. The oscillator must often be followed by several multiplier and converter stages to yield the necessary frequency deviation.

The introduction of an amplifier before or after the phase splitter makes possible greater deviation. Because the phases in this amplifier affect the stability of the oscillator, only one stage can usually be used.

Circuit Simplification

The simplest arrangement is to use the dynamic plate resistance of the amplification tube as the resistance of the phase shifter as is done in Fig. 2A. If this tube has a high plate resistance, the voltage appearing across the reactance is shifted nearly 90 degrees. This reactance can be either an inductance or a capacitance. The reactive current delivered to the tank circuit can be modulated by changing the effective mutual conductance of one or more of the tubes associated with it.

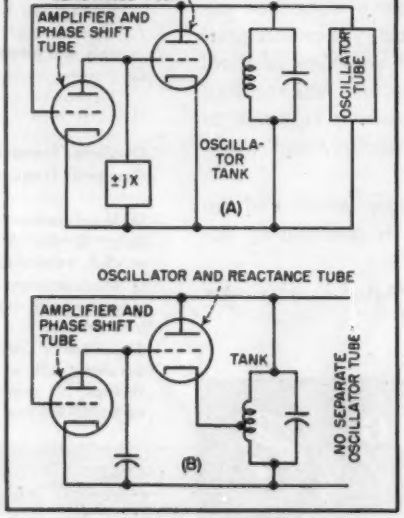


FIG. 2—Improved f-m oscillators

At very high frequencies only the tube capacitances need be used for the reactive component of the phase shifter. *At higher frequencies the transit time in the reactance tube can supply the 90 degree phase shift so that a single transit-time reactance tube replaces the two tubes.* Otherwise the effect of transit time can be counteracted by adjustment of the phase shifter.

The circuit can be simplified still further by using the oscillator tube simultaneously as the reactance tube as shown in Fig. 2B.

Practical Execution

To obtain the largest possible frequency deviation with good stability, it is necessary to limit the amplitude of operation to the linear portion of the grid characteristic of the amplifier. A crystal diode can provide this limiting.

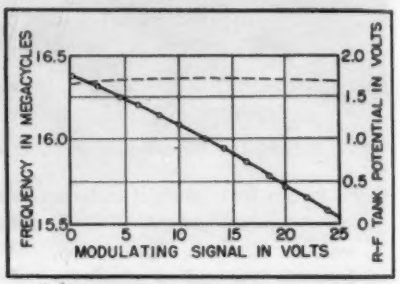


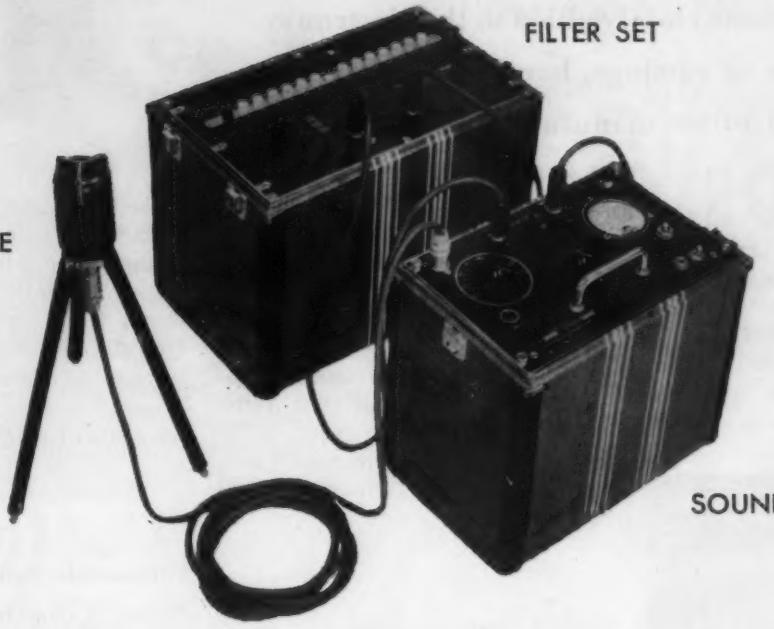
FIG. 3—Typical experimental results

The fact that the tank circuit capacitance is distributed over the several tubes of the system must be taken into consideration. If, at vhf, the inductances of the tube connections are too near that of the tank circuit, and the reactance tube supplies a strong reactive current, oscillation may be unstable. This condition can be avoided by increasing the inductance of the tank circuit, decreasing the tube capacitances, and decreasing the inductances of the connections, possibly by concentrating all the tubes in one envelope.

Using the oscillator tube as the reactance tube also, and using low transconductance tubes, linear deviation and constant amplitude of

(Continued on p 168)

Ready to help you lick noise and vibration problems!



A sturdy, dependable, portable noise analyzer

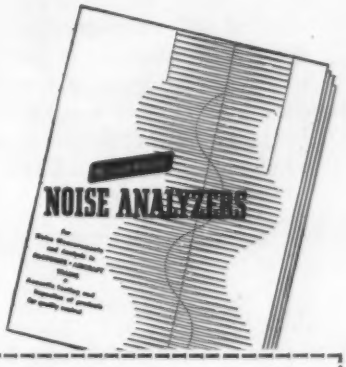
This Western Electric Noise Analyzer is ideal for noise measurement and analysis (where a detailed analysis of the noise into specific frequency components is not required) and for acoustic testing and inspection.

This analyzer helps you solve many problems where a sound level meter *alone* would be of little value. A multiple push-button switch permits selection of any one of 13 high pass or 13 low pass filters at approximately half octave spacing, or the 12 octave bands between the high and low pass sections. The insertion loss of the filter set is automatically compensated for and no corrections to readings are required.

In addition to the non-directional moving coil mike provided with the Noise Analyzer, you may also wish to order a Vibration Pick-up to measure vibrations not accompanied by noise.

The Noise Analyzer is available in A-C line and battery operated models. For full information, send the coupon or call your Graybar Representative.

Send for this Bulletin today



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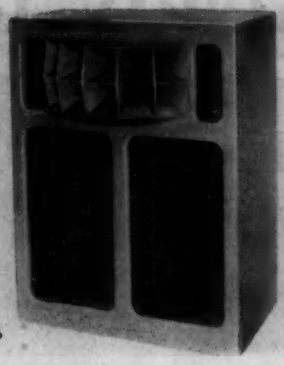
NEW PRODUCTS

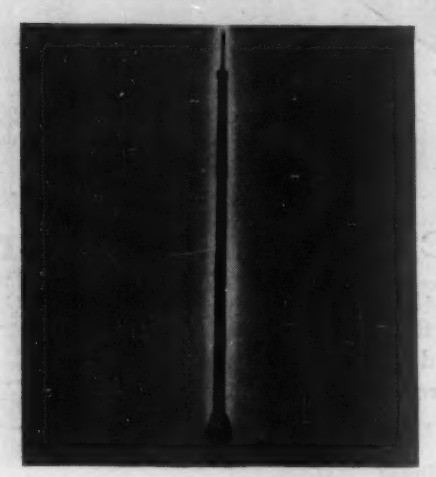
Edited by A. A. McKENZIE

New equipment, components, tubes, testing apparatus and products closely allied to the electronics field. A review of catalogs, handbooks, technical bulletins and other manufacturers' literature



High-Gain Antenna

THE WORKSHOP ASSOCIATES, INC., 66 Needham St., Newton Highlands 61, Mass. Model 3HW high-gain beacon antenna was designed for the 152- to 162-mc mobile communication band. The unit comprises three half-wave dipoles



stacked 0.7 wavelength apart and driven in phase. It can be fed with various types of transmission lines by means of special connector adaptors. Total weight is less than 40 pounds and price is $300.

STL for F-M

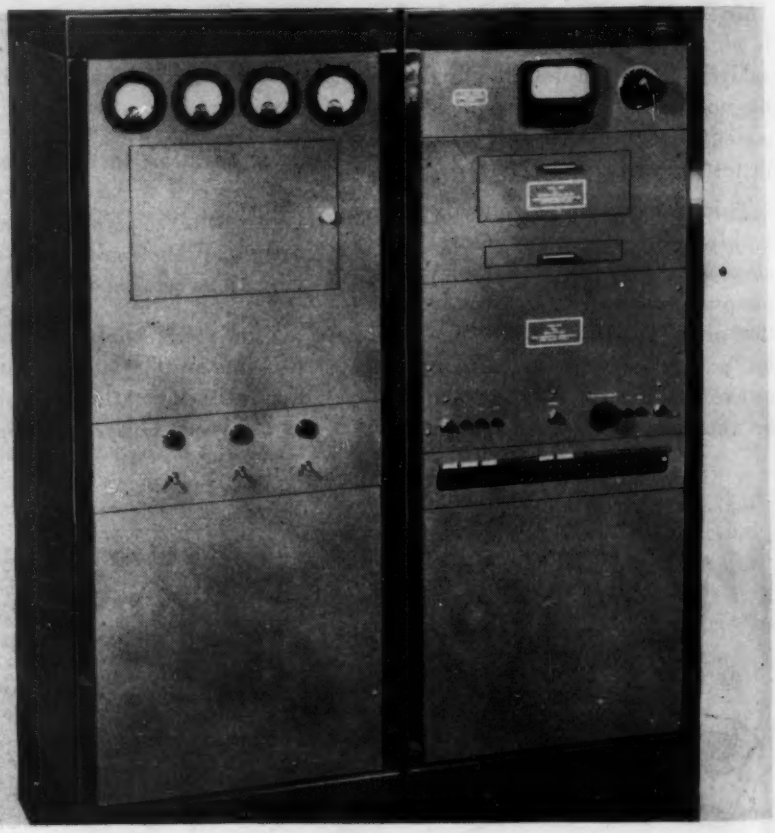
RADIO ENGINEERING LABORATORIES, 35-54 Thirty-Sixth St., Long Island City 1, N. Y. Model 694 studio-transmitter link equipment operating in the frequency range between 940 and 960 megacycles comprises special receiving equipment and an entirely new transmitter. Overall system performance from transmitter input to receiver output gives signal-noise ratio better than 75 db below 100 percent modulation. Audio response is within 0.3 db from 50 to 15,000 cycles. Distortion is no greater than 0.3 percent at 100 percent modulation over the entire audio range. With the unique Serrasoid modulator only 750 watts of total transmitter input power is required for adequate signalling over a 30-mile path. Frequency is directly crystal controlled.

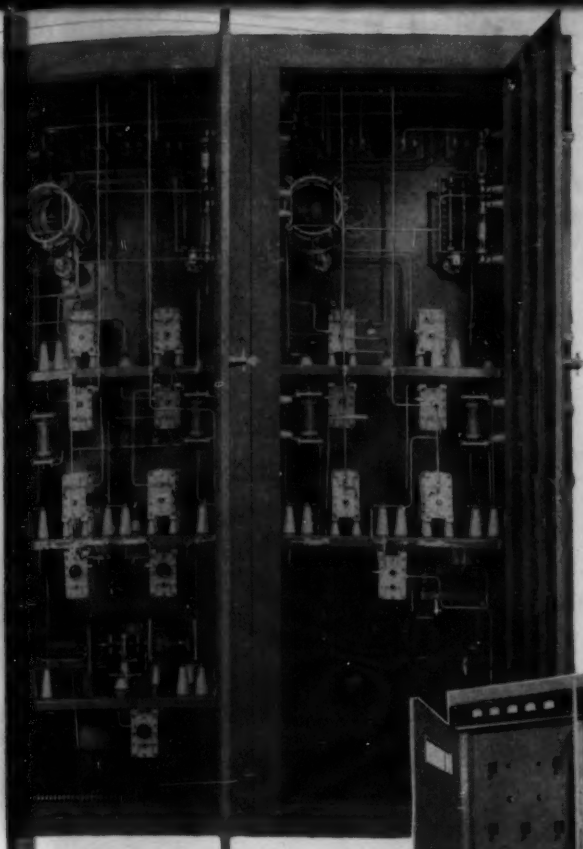
High-Level Speaker

STEPHENS MANUFACTURING CORP., 10416 National Boulevard, Los Angeles 34, Calif. Designed for deluxe home installations, Tru-Sonic model P-63HF speaker system is built along the lines of commercial theater equipment. Two speakers are used with crossover at 600 cycles. Overall frequency range is from 30 to beyond 15,000 cycles. The equipment described in Bulletin 109 weighs 245 pounds.

Ultrasonic Sound Pressure

MASSA LABORATORIES, INC., 3868 Carnegie Ave., Cleveland 15, Ohio. Model GA-1005 sound pressure measurement system comprises model M-113 microphone, M-114





OUBLE CUBICLE, 5 KW UNIT, rear ew, showing the compact but un-owded arrangement of compo-nts. Large rear doors are interlocked r safety, provide easy access for aintenance or adjustment.

RAYTHEON

Excellence in Electronics

and in Directional Antenna

PHASING EQUIPMENT

TRIPLE CUBICLE, 10 KW UNIT shows convenient arrangement of power and phasing controls, line current and input meters. Counters and panel lights indicate the setting and directional pattern in use. Safety doors exclude unauthorized personnel. NOTE: Cabinet design and number of cubicles is determined by equipment required — not necessarily by KW output.

SINGLE CUBICLE, 1 KW UNIT illustrates the handsome appearance of the heavy gauge steel and channel iron cabinet. Modern two-tone chrome-trimmed design adds smart style to any station.

aytheon's specialists, cooperating with your consultant and ation engineers, are prepared to custom-build directional ntenna phasing and tuning equipment that will produce ptimum results with your proposed or existing transmitting quipment. Engineered for maximum efficiency and stability . . designed for utmost ease, economy and safety of operation . . . styled for ultimate appearance, convenience and ccessibility — in the size to suit the power and special characteristics of your installation.

PROMPT DELIVERY . . . usually in 60 days or less. Call your Raytheon Broadcast Representative for complete information or — Write for Bulletin DL-R-444.

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Raytheon Manufacturing Co.
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Republic 5897

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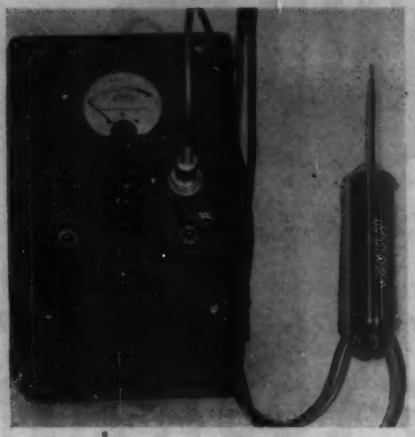
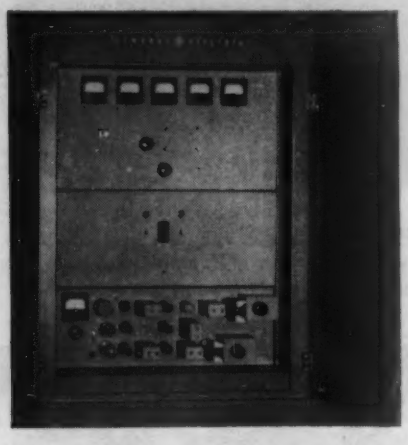


preamplifier, and model M-116 power supply. Precise measurements of absolute sound pressure over the range 50 cycles to 250 kilocycles are possible. The equipment permits special acoustic measurements such as analysis of the sound spectrum from jet engines.

Relay Link

GENERAL ELECTRIC CO., Syracuse, N. Y. Studio-transmitter relay link equipment type BL-2-A operates in the band between 920 and 960 megacycles. Noise level is at least 65 db below 100 percent modulation. Harmonic distortion is less



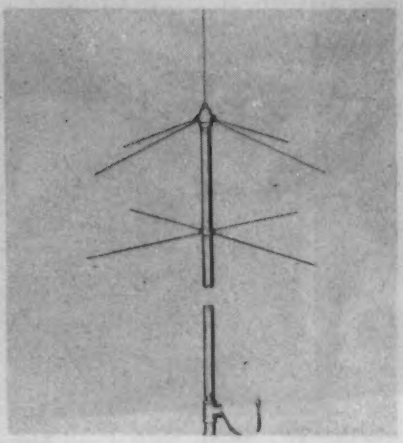
than 1 percent from 50 to 15,000 cycles, and audio response is within plus or minus 1 db, these measurements being overall from transmitter input to receiver output. Two 40-inch parabolic antennas are used.

Audio Tape

AUDIO DEVICES, INC., 444 Madison Ave., New York, N. Y. Audiotape is a vinyl plastic tape treated with a magnetic oxide. When run at a speed of 150 feet per minute it has a frequency response flat to above 15,000 cycles. It can be supplied in limited quantities for test purposes and full production is expected soon.

Ground Plane Antenna

MOTOROLA INC., 4545 Augusta Blvd., Chicago 51, Ill. The Isoplane antenna designed for the frequency



band between 152 and 162 megacycles is an inexpensive device for pickup, monitor receiver, or central station antenna. The design permits exact matching of antenna and leadin cable for low standing wave ratio.

Distortion-Noise Analyzer

GENERAL ELECTRIC CO., Syracuse, N. Y. Type YDA-1 distortion and noise analyzer will measure distortion down to 0.1 percent, measure hum or noise present on an audio signal, act as a high-sensitivity vacuum-tube voltmeter, perform as a frequency meter over the range

50 to 15,000 cycles. It is designed for television broadcast, and research applications.

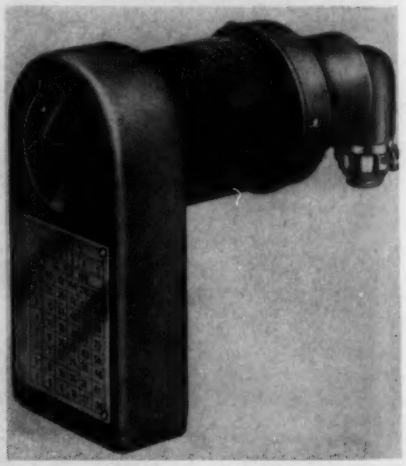
Group Audiometer

GRAYBAR ELECTRIC CO., 420 Lexington Ave., New York, N. Y. Model 4CA is a group audiometer providing facilities for testing the hear-

ing of from one to forty persons at a time. It is independent of external power sources. A spring-wound motor maintains constant record speed, and long-life batteries supply steady voltage to the vacuum-tube amplifier.

Hydraulic Oscilloscope

K & K ENGINEERING CO., Bolton, N. Y. The Stroboflow comprises a precision turbine that rotates at the



speed of liquid flow. Rotor's speed is determined from the stroboscopic

(continued on page 190)

Voice of America!...

...ON audiodiscs*

The Voice of America gives to other nations a full and fair picture of American life, aims and policies, plus factual news of the world and the United States.

Broadcast in twenty-three languages, these programs blanket Europe, Latin America and the Far East, with a potential radio audience of more than 150,000,000 persons.

Of the thirty-two hours of daily broadcast, approximately one-fourth of the time is devoted to news, one-half to additional comment and informational programs, and the remainder to music and entertainment.

A substantial part of these daily programs is recorded and, due to the excellent quality of these transcriptions, such recorded portions cannot be distinguished from the *live* transmissions.

Today, as from the beginning, the recorded parts of these broadcasts are on AUDIODISCS.

AUDIO DEVICES, INC., 444 Madison Avenue, New York 22, N.Y.

Export Department: Rocke International Corp., 13 E. 40th Street, New York 16, N. Y.

Audiodiscs are manufactured in the U.S.A. under exclusive license from PYRAL, S.A.R.L., Paris

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NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

IRE seeks new frequency designations; programs of spring conferences; new FCC questions for operator exams

Citizens Radio Equipment Approved by FCC

THE FCC has issued the first certificate of type approval for equipment to be used in Citizens Radio Service—a radio transceiver designed by Citizens Radio Corp., Cleveland, Ohio, to operate on a frequency of 465 megacycles. Tests show the unit complies with the provisions of Part 19 of the Commission's rules governing Citizens Radio Service. The apparatus weighs about 2½ pounds with batteries and is comparable in size to a camera and carrying case.

Issuance of this type-approval certificate marks the advent of a a new service which will be available to individual citizens for personal use in the 460 to 470-mc band. Stations now in operation are authorized as class 2 experimental stations. This approval of the FCC forecasts early availability of manufactured units suitable for this service. The Commission has under consideration establishment of additional rules to provide for simplified licensing for operation by individuals.

Medical Education by Television

NORTHWESTERN UNIVERSITY medical school will use television to bring to the estimated 18,000 physicians and surgeons attending the American Medical Association meeting in Chicago, June 21 through 25, five days of programs showing both surgical procedures and clinical demonstrations.

Among the televised programs will be obstetrical and gynecological procedures, including a caesarian section; the blue-baby operation; early skin grafting in severe burns; gastric resection; hand surgery and chest surgery. The video camera will also reproduce clinical material in the fields of internal medicine, orthopedics, cancer, dermatology, endocrinology and neurology.

Radio for Circus Traffic

RINGLING BROTHERS Barnum and Bailey Shows, Inc., was granted a construction permit for 15 portable and mobile radio units in the experimental service for use in directing the loading, unloading and transporting of exhibition equipment. Radio transmitter-receivers will be installed on railroad cars and circus vehicles which move equipment between railroad sidings and show grounds.

Radar-Mapping Australia

LINCOLN BOMBERS, assisted by mobile radar stations, will soon photograph the terrain and establish radar control suitable for small-scale mapping of Australia.

To ensure that there are no gaps in aerial photography, British equipment, involving the use of one or more G-H stations, will be used in the radar photographic program. To determine the actual position of each photograph it is necessary to have a second G-H station in operation simultaneously.

Television Network Extensions

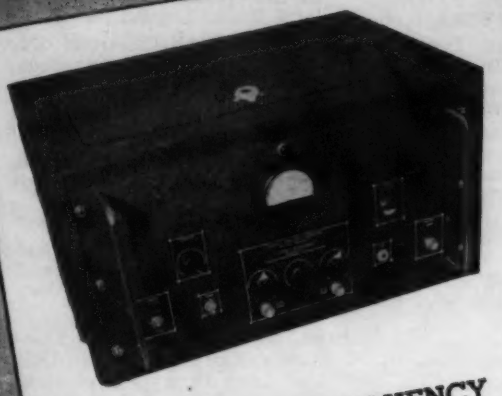
PLANS HAVE BEEN made by the American Telephone and Telegraph Company to provide additional intercity network facilities this year from the east coast to the Mississippi River. New networks to be built in the midwest and the east will be linked by connecting Phila-

MICROWAVES CLEAR MOUNTAINS

An experimental multichannel vhf radiotelephone toll link has been set up between Johnstown and Northville, New York. Elevation of both ends of the radio link, as indicated on map (lower right), provides a line-of-sight path for the 26-mile stretch

Lavoie

UHF PRECISION INSTRUMENTS



HARMONIC FREQUENCY GENERATOR

PROVIDES output voltages in 10 or 40 megacycles with CRYSTAL-CONTROLLED accuracy.

SELECTS 10 or 40 megacycle series by means of front panel switch.

IDENTIFIES any one of these harmonics by means of a Frequency Identifier* which consists of a filter providing high attenuation of all voltages except that of frequency to be identified.

USED FOR calibration of receivers, wavemeters, or (with Beat Detector built into instrument) for calibration of oscillators and signal generators

* Specify frequency.

PRECISION FREQUENCY METER

Completely portable Accuracy 0.1%
Battery or AC-Operated

Models available from 100 to 1500 megacycles with 2 to 1 frequency coverage on each model. Available only on high priority while nation is at war.

RECOMMENDED FOR:

- Production testing
- Measurement of oscillator drift
- Independent alignment of transmitters and receivers
- Precise measurements of frequencies

FULL DETAILS ON REQUEST

U H F

Lavoie Laboratories

RADIO ENGINEERS AND MANUFACTURERS

MORGANVILLE, N. J.

Specialists in the Development of UHF Equipment

delphia and Cleveland with coaxial cable. Other sections will use both coaxial cables and microwave radio relay systems. It is expected that by the end of the year the same television program can be broadcast simultaneously by stations in cities linked to the network from Boston to St. Louis.

Facsimile for Newspapers

SPECIAL TESTS were recently conducted by the Miami Herald to determine the feasibility of facsimile in newspaper production. Favorable reaction was indicated when a picture of an accident casualty being placed in an ambulance was printed on a facsimile receiver before the victim had reached the hospital.

Facsimile transmitter rolls out newspaper

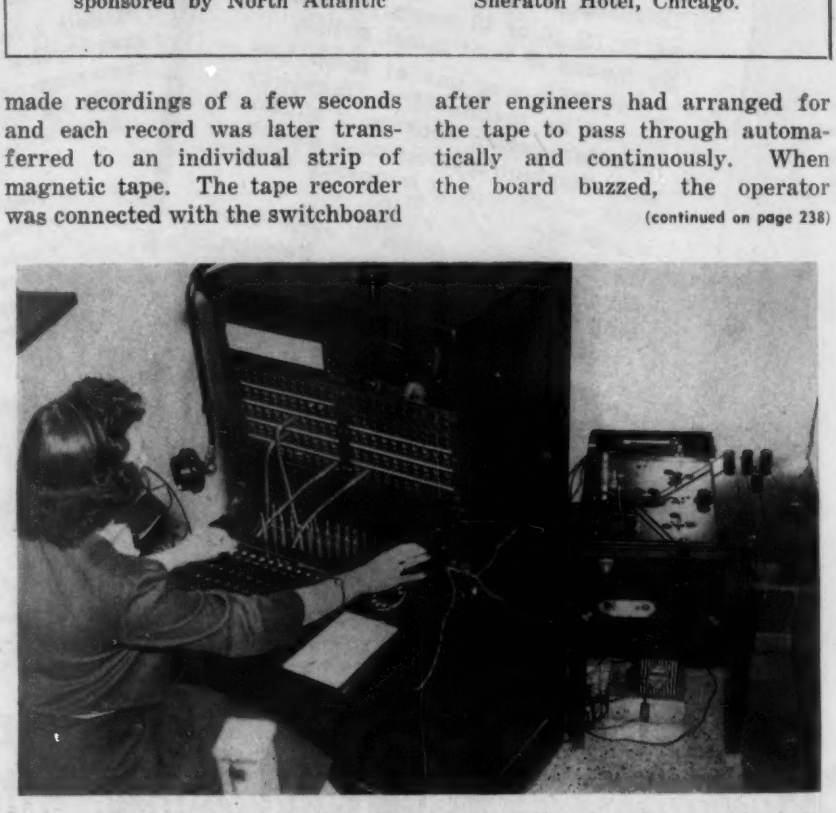
The southern newspaper will place several General Electric sets in operation in a study of editorial production methods and problems.

Broadcast Promotion Via Tape

RADIO STATION KDKA, Pittsburgh, Pa., recently attempted a novel promotional stunt with gratifying results. Each telephone call to the station was answered immediately by a featured NBC performer promoting the evening's broadcast, and then the regular operator would cut in. In a short time the switchboard was overloaded with calls.

The trick programming was accomplished by tape recording. Some twenty of NBC's outstanding stars made recordings of a few seconds and each record was later transferred to an individual strip of magnetic tape. The tape recorder was connected with the switchboard after engineers had arranged for the tape to pass through automatically and continuously. When the board buzzed, the operator

(continued on page 238)



Tape recorder feeds voices of radio favorites into switchboard at the press of a button

MEETINGS

APRIL 24: Spring Technical Conference of IRE Cincinnati Section, featuring television papers, at Engineering Society Headquarters.

APRIL 26-28: IRE-RMA spring meeting on transmitters, Syracuse Hotel, Syracuse, N. Y.

APRIL 28-30: AIEE North Eastern District Meeting, New Haven, Conn.

MAY 3-5: URSI-IRE joint meeting, Washington, D. C.

MAY 9-14: 1948 Radio Parts Show, Hotel Stevens, Chicago.

MAY 11-16: Engineering Progress Show, Franklin Institute, Philadelphia, Pa.: exhibits and two evening lectures.

MAY 17-21: 63rd semiannual convention of the Society of Motion Picture Engineers, at the Ambassador Hotel, Santa Monica, Calif.

MAY 19: Meeting, American Ceramic Society; at 1 West 52nd St., New York City; 5:00 p.m.—The Chemistry of Glass-Metal Seals, by A. J. Monack, consulting engineer; dinner; Ceramic Developments in the Electronic Field, by B. S. Ellefson of Sylvania.

MAY 20-21: Broadcast Engineering Conference, Los Angeles, Calif. (NAB Convention).

MAY 22: Second New England Radio Engineering Meeting, sponsored by North Atlantic Region of IRE, at Hotel Continental, Cambridge, Mass.

JUNE 21-25: 51st annual meeting of the American Society for Testing Materials, at Detroit, Michigan.

JUNE 21-25: AIEE Summer General Meeting, Mexico City.

JULY 14-16: International symposium on noise, held by the Acoustics Group of the Physical Society and the Roger Institute of British Architects, at the Royal Institute, Portland Place, London, W. 1.

AUG. 20-29: All-Electrical Exposition, Pan-Pacific Auditorium, Los Angeles, Calif.

AUG. 24-27: AIEE Pacific General Meeting, Spokane, Wash.

SEPT. 13-17: Third Instrument Conference and Exhibit, Convention Hall, Philadelphia, Pa.

SEPT. 27-OCT. 2: Third National Plastic Exposition, Grand Central Palace, New York City.

SEPT. 30-OCT. 2: Pacific Electronic Exhibition and IRE west coast Annual Convention, Biltmore Hotel, Los Angeles, Calif.

OCT. 5-7: AIEE Middle-Eastern District Meeting, Washington, D. C.

OCT. 11-12: FM Association Second Annual Convention, Sheraton Hotel, Chicago.

Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS

DYNAMOTORS FOR QUICK DELIVERY!

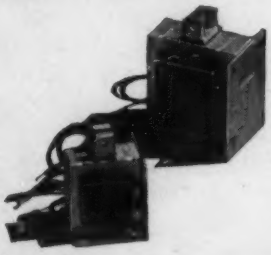
Shopping for fractional-hp dynamotors? General Electric can now supply you on a short-shipment basis! Production has finally caught up on these d-c

to a-c converters for communications service. Standard dynamotors are available in ratings of 200 and 500 volt-amperes, 60 cycles, continuous duty. Specials are also available, but on a slightly longer shipment For more complete information on these fhp equipments, contact your G-E representative or write Fractional-horsepower Motor Div., General Electric Co., Fort Wayne, Indiana.

MORE PULL IN LESS SPACE

You'll find these new, small, all-welded solenoids useful in any application where a straight-line thrust is required . . . they're a natural for vending machines. The small unit requires only three cubic inches of space, and develops 0.26 pounds pull at ½-inch stroke; its "big brother" produces 3.7 pounds at ¾-inch stroke.

Brazed-in pole shader increases efficiency, insures quiet operation. Varnish-impregnated coil provides high resistance to shock, splashing water, oil. Check Bulletin GEA-4897.



SHOW IT, THEN THEY'LL KNOW IT

If your organization has an educational program underway, or plans one, ask your G-E representative to show you the Industrial Electronics Training Course. Rated tops in visual training by the nation's industrials, schools and institutions now using it, the complete kit contains twelve half-hour slide films with records, individual lesson guides keyed to the film, and a manual for the course instructor.

Everything from fundamental electronics to up-to-the-minute electronic

production tools are forcefully described and explained in this easy-to-take visual course. Check Bulletin GES-3303.

NEED SOMETHING SPECIAL IN CAPACITORS?

Here's a new .0075-muf, 10-kv d-c capacitor for television, precipitation, and similar electronic equipment requiring filtering in high-voltage power supply. Other capacitances (.0005 to .01 muf) and voltages (3 to 30 kv) can be supplied.

Ceramic container acts as insulator, simplifies mounting, cuts size (volume) to 1/5th without lowering quality in any way. Ingenious internal hermetic silicone seal eliminates solder. Pyranol filled. Contact your G-E representative or write Transformer Div., General Electric Co., Pittsfield, Mass., for quotation.

LOOKING FOR PERMANENT MAGNET DATA?

These two new bulletins are packed full of application and design information to help you build magnets into your electronic equipment. CDM-1 covers "Permanent Magnets"; CDM-2 describes "Cast and Sintered Alnico Magnets." Coupon below will bring this valuable information to your desk quickly. Check it now.

GENERAL ELECTRIC COMPANY, Section A642-17
Apparatus Department, Schenectady, N. Y.

Please send me the following bulletins:

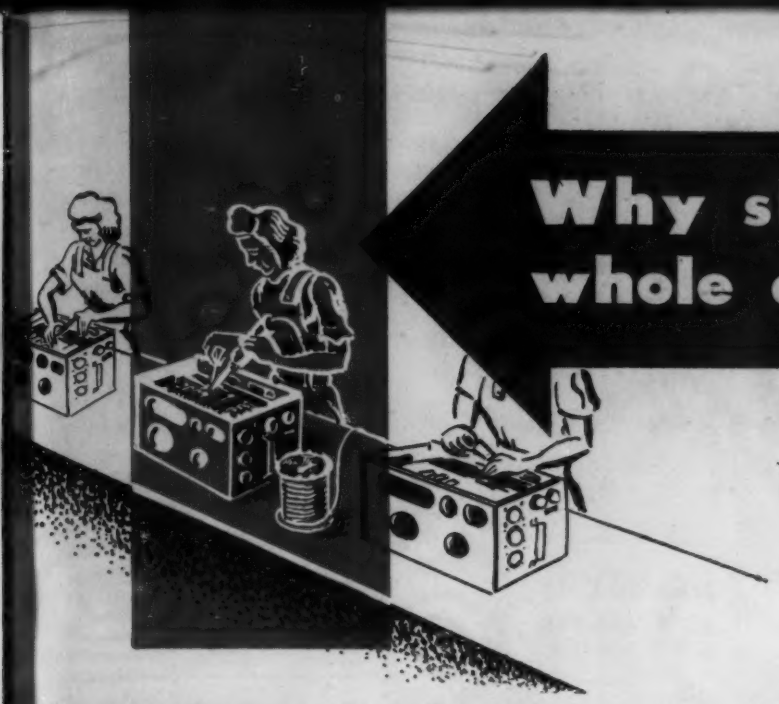
- ☐ GEA-4859 Telephone-type Relay
- ☐ GES-3303 Electronics Training Course
- ☐ GEA-4864 Appliance Relay
- ☐ CDM-1 Permanent Magnets
- ☐ GEC-257 General-purpose Relay
- ☐ CDM-2 Cast & Sintered Alnico Magnets
- ☐ GEA-4897 Solenoids

Name.....

Company.....

Address.....

City.....State.....



Why slow down the whole assembly line?

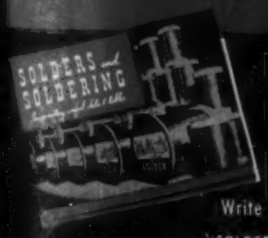
For continuous performance use the only 3 core solder made with ERSIN FLUX--The original non-corrosive, extra-active flux

ERSIN Multicore

One tough soldering operation can slow the pace of a whole assembly line. Try Ersin Multicore on the toughest soldering job in your plant. Note how the incomparable Ersin Flux reduces the surface tension of molten solder, — how it wets metals faster, — how it gives maximum and speedy fluxing action and greater coverage in less time.

A number of the industry's most prominent manufacturers have tested Multicore, seen for themselves, and are now using it exclusively.

AVAILABLE IN ALL ALLOYS AND GAUGES.



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Address U.S.A. and Canadian inquiries to:

BRITISH INDUSTRIES CORP.
315 Broadway, New York 7, N. Y.

Inquiries regarding other territories to:

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LOW-RESISTANCE TEST SET #670C
1,000 to 500,000 micro-ohms
(Other ranges from 200 micro-ohms to 100 ohms)

KILOVOLTMETER #785P
AC-DC 5-10-20 KV
(Other ranges from 1.5 to 200 KV)

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KELVIN-WHEATSTONE BRIDGE #638-2
0.0001 ohm to 11.11 megohms
(7 additional designs and 15 types of

DECADE BOX #825
11,110 ohms in 1 ohm steps
(Other designs, 1 to 7 dials, from 0.1 to 11,111,110 ohms)

. . . for electrical measurements

VOLTAGE DIVIDER (Decade Potentiometer)
10,000 ohms total. Voltage ratio: 0.001 to 1.0
(Other 3- and 4-dial designs, 1,000 to 100,000 ohms)

Shallcross Electrical Measuring Instruments are made in many types — from sturdy, inexpensive bridges for school and production use, to fault location bridges, high-voltage test equipment, low-resistance test sets and numerous others.

Write for Bulletin on any type.

AKRA-OHM PRECISION RESISTORS
14 Standard Types.
50 available special designs.

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350 designs for instruments and high-grade electrical apparatus.

ATTENUATORS & CONTROLS FOR COMMUNICATION EQUIPMENT

Shallcross Manufacturing Co.
Electrical Measurement Specialists
Dept. E-58 Collingdale, Pa.

(continued from p 130)

ated by the tube V_1 in the variable frequency section is achieved by altering the effective resistance of one element in the phase-shifting network. This could be done by inserting a normal variable resistance in series with one of the fixed resistances, but here the same effect is secured by varying the grid bias of tube V_2. This tube is a cathode follower, the output impedance of which shunts the center resistance of the phase-shift network. The output impedance is a function of the grid bias on the tube that is controlled by potentiometer R. In short, the frequency of the oscillations generated by the variable oscillator, and hence the resulting tone frequency, is determined by the setting of R.

Potentiometer R may be mounted at any desired distance from the apparatus. The lead from its slider carries no current and can therefore cause no instability, however long it is. The potentiometer dial can be calibrated in frequency.

In practice, both oscillators are set to the same frequency (about 100 kc) with V_2 biased almost to cutoff, but if V_2 has a variable-mu characteristic it need not be biased so far back as might otherwise be necessary.

Instead of a cathode follower for frequency control, a negative-resistance transitron could be used and in this case the magnitude of the negative resistance is a function of the grid bias.

Capacitors and Selenium Rectifiers

By F. Parmly and E. Sherich
Engineering Department
Cornell-Dubilier Electric Corp.
South Plainfield, N. J.

When electrolytic capacitors are used in rectifier circuits with selenium cells, the capacitors are often subjected to severe operating conditions, including high values of ripple current.

Ripple voltage has the effect of decreasing the life of the electrolytic capacitor by increasing the heat generated and therefore the leakage current. It also tends to reduce the effective value of the capacitance. This effect is caused by

SELECT from the

Techniquality GROUP

Bliley CRYSTALS

Many Bliley crystal units are first produced on a custom-built basis for special application. Quite often these designs contain outstanding features that are desirable in many applications and when this occurs the unit is included in our catalog listing. Our Bulletin 36 contains 22 standard crystal units, all widely used in commercial and governmental applications.

Bliley engineers are constantly utilizing our many years of specialized experience to solve new frequency control problems. If you have a frequency control application, whether standard or specialized, we can probably come up with the right answer. Remember to specify Bliley TECHNIQUALITY crystals for greater accuracy, stability, quality, and advance design.

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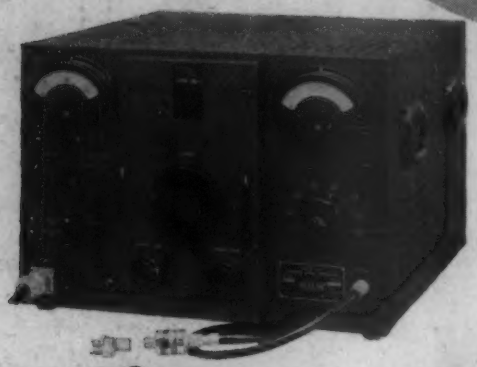
BLILEY ELECTRIC COMPANY • UNION STATION BUILDING • ERIE, PENNSYLVANIA

VHF-UHF WATTS "BOTTLED UP"!

M. O. P. A.
2C39 OSCILLATOR
2C39 AMPLIFIER



POWER TO DRIVE AN ANTENNA
160 db
MICROVOLTS TO MEASURE RECEIVER SENSITIVITY

40MC-400MC

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MODEL 30
POWER TYPE
STANDARD SIGNAL GENERATOR

- 5 WATTS NOMINAL R-F OUTPUT — 50 OHM IMPEDANCE.
- 160 DB RANGE OF ATTENUATION — 15.0 VOLTS TO 0.10 UV.
- CW — AM — PULSE OPERATION.
- MASTER OSCILLATOR — TUNED POWER AMPLIFIER CIRCUIT.
- CONTINUOUS TUNING 40MC TO 400MC — SPIRAL DIAL SCALE 4 FEET LONG
- DIAL CALIBRATED AT INTERVALS OF 1% IN FREQUENCY.
- LEAKAGE FIELDS LESS THAN .1 UV/METER.

Write for details ROLLIN

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2070 N. FAIR OAKS AVE. • PASADENA 3, CALIF.

cathode foil formation which acts as a capacitance in series with the original anode capacitance, thus reducing the overall effective capacitance. The use of a too-low capacitance in a circuit must be avoided, since the lower the capacitance, the higher the ripple voltage.

Current-limiting Resistors

Whenever practicable, the use of a current-limiting resistor in selenium rectifier circuits is recommended. Without a protective resistor, charging current of the capacitor may reach an excessive value that may ruin the selenium cell and cause untimely failure of

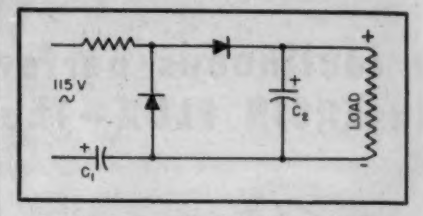

FIG. 1—Series line-feed voltage doubler

the capacitor. Since the peak charging current increases with the size of the capacitor, the size of the capacitor must be limited so that failure of the selenium cell will not be accelerated.

Severe reverse current surges, which occur in all selenium cells during re-formation of the barrier layer, may last for several minutes. During such periods, associated capacitors are subjected to abnormal reverse currents and voltages. Excessive heating and tendency to cathode foil formation take place much as when ripple currents are too large.

An adequate protective resistor limits charging current and reverse current surges to values which are within reasonable safety limitations.

Capacitor ratings are based also upon maximum ripple voltages, which in turn depend upon normal line voltages. A resistor included in the circuit guards against damage from high line voltages.

With current-limiting resistors, there is a slght decrease in output voltage and slightly poorer voltage regulaton. For improvement in output voltage and regulation, the resistance used may be decreased; but this is at the cost of less safety,

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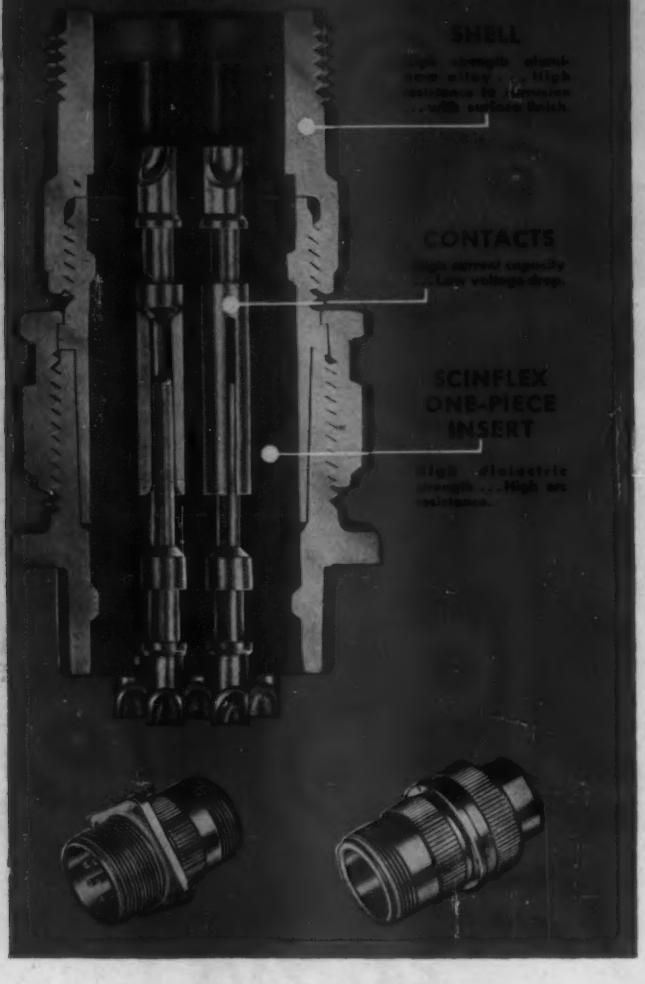
the finest ELECTRICAL CONNECTORS money can build or buy!



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greater capacitor ripple current and therefore greater capacitor size and cost.

A value of 50 ohms has been found generally acceptable; this conservative figure may be reduced where current demand is not excessive.

Capacitor Selection

The following factors determine the capacitor suitable for a particular selenium rectifier circuit: no-load and full-load d-c working voltage, full-load rms ripple current through the capacitor, ripple frequency, and maximum ambient temperature at which the capacitor will operate.

Where high ripple current is encountered, an aluminum-contained capacitor is recommended. The heavy ripple currents cause cardboard-contained capacitors to dry out quickly.

Half-Wave Circuit

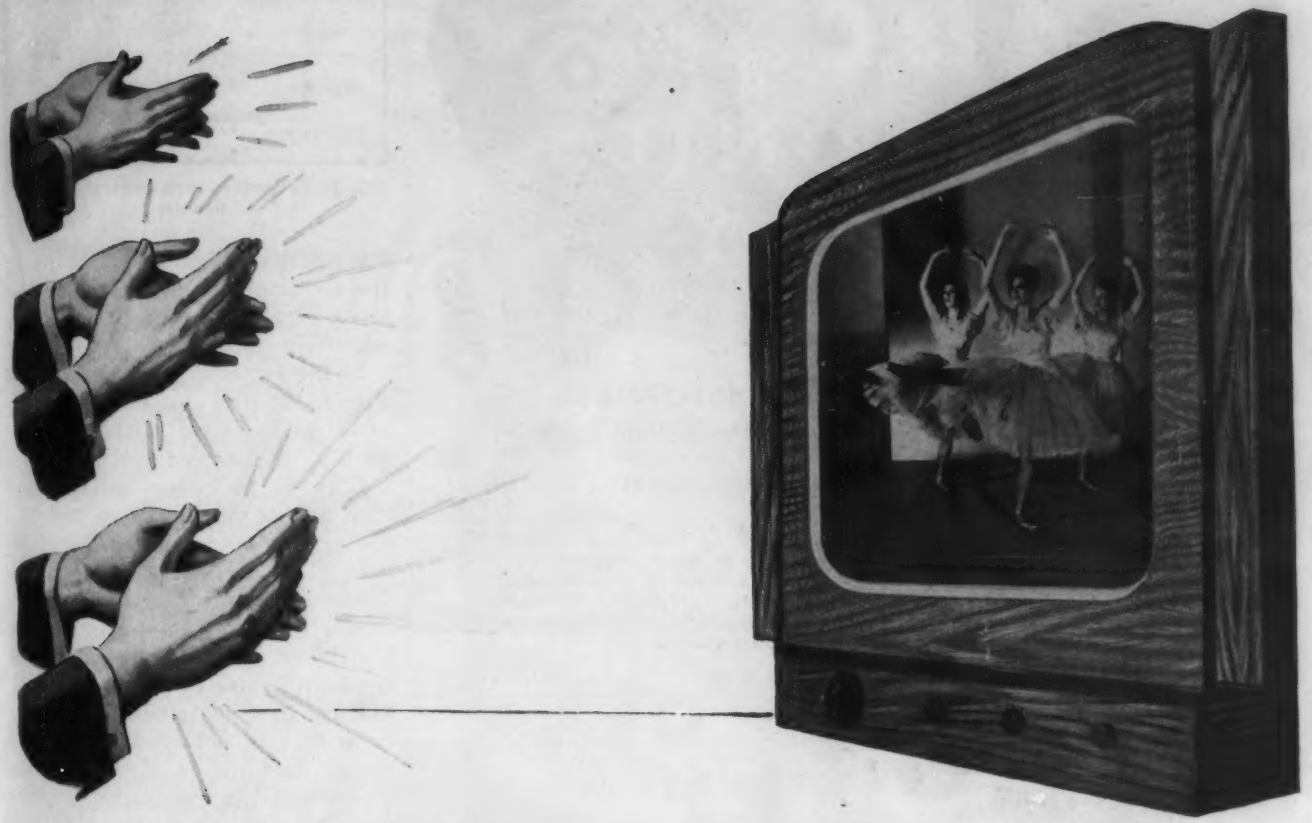
The choice of a capacitor suitable for the half-wave circuit depends chiefly upon d-c output current desired and maximum permissible ripple voltage.

The capacitance needed for a particular value of ripple voltage can be calculated. In the time $1/f$ (for one cycle) the capacitor discharges through the load at an approximately constant rate, $I_{D\text{-}C}$. The capacitor loses an amount of charge $I_{D\text{-}C}/f$. Therefore its voltage changes by the amount $V = I_{D\text{-}C}/fC = Q/C$. Hence the ripple voltage is: $V_R = I_{D\text{-}C}/fC$. And the capacitor needed is: $C = I_{D\text{-}C}/fV_R$.

Since the discharge current does not decrease exactly linearly with time, but varies exponentially, a slight error is introduced. The error is on the side of caution, since the calculated value will be slightly larger than the C actually required. Thus the C used may be slightly lower than the value calculated, but too great a reduction will result in larger ripple currents and voltages and a shorter capacitor life.

In simple half-wave circuits, all electrolytic capacitors, including filter and bypass sections, may be incorporated into the same container, as a common negative terminal may be used for all sections.

In full-wave doubler circuits, two rectifiers operate alternately on



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series in the circuit and leakage currents between them would be high. However C and any additional bypass capacitors may be placed in the same container, because they have a common negative terminal.

Automatic Lighting Switch

By Carl C. Smith
Electronic Consultant
Niagara Falls, Canada

MANY circuit arrangements designed for automatic control of lighting circuits with decreasing daylight incorporate time-delay networks, inverse feedback and a number of other auxiliary circuits to improve the overall response of the equipment to the initiating variable for which they are designed. The equipment to be described affords reliable operation over long periods of time with minimum tube or accessory replacements.

Essentially, the unit consists of a photoemissive tube of selected spectral characteristics whose output is amplified to a current value sufficient to operate a sensitive relay in the plate circuit of the output tube. The value of this relay current is adjustable over a wide range by means of a current-adjusting potentiometer in this circuit.

The input sensitivity of the device is adjustable by means of a bias potentiometer in the grid circuit of the input tube. Since, in this amplifier, the output (and relay) current increases with increased light on the photoelectric surface, the armature of the sensitive relay is pulled in with light values on the phototube which exceed a predetermined value.

The controlled lighting circuits are opened or closed by auxiliary magnetic contactors capable of handling the lighting load to be controlled, the sensitive relay operating the coil of the magnetic contactors only. With normal values of light on the phototube, the sensitive relay contacts which operate the auxiliary relays are opened, thereby deenergizing the circuits. When the daylight value decreases below the preset value, the sensitive relay armature drops out, closing the load circuit contac-

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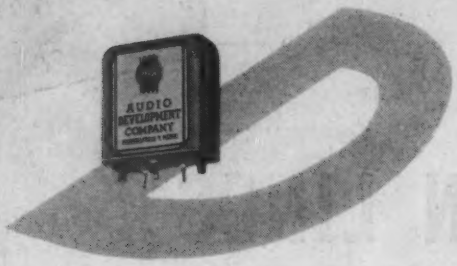

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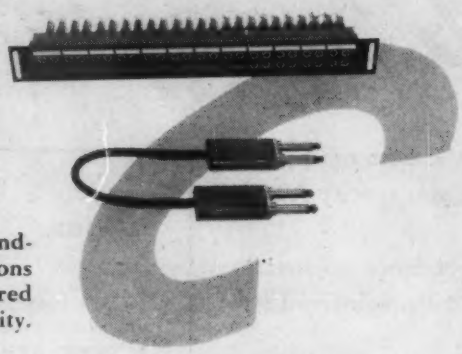

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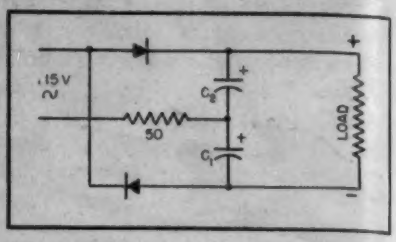

FIG. 2—Full-wave symmetrical voltage doubler

the positive and negative loops of the a-c line voltage to charge the input capacitors, which discharge additively into the load.

In the series line-feed circuit of Fig. 1, the first capacitor C_1 is in series with one leg of the line. It doubles the load voltage by charging up to peak line voltage and then adding its charge to the line during each succeeding cycle. However C_1 impresses a large ripple voltage upon the load. To reduce this ripple voltage C_2 is added. Usually an additional L-C line filter is placed before the load.

A common container for all the capacitors is not advisable. The ripple currents in C_1 are much higher than any others and cause greater heating of C_1, and if C_1 and C_2 were in the same container C_2 would become unnecessarily heated in circuits having large load and ripple currents. Filter and further bypass capacitors may be put in one container.

For small load and ripple currents, the peak voltage rating of C_2 and following bypass capacitors must be almost double peak line voltage, if no 50-ohm resistor is used, and may be about 10 percent less if a resistor is used (depending upon circuit constants.) The peak voltage rating of C_1 must be at least peak a-c line voltage.

Symmetrical Doubler Circuit

In symmetrical voltage-doubler circuits, such as Fig. 2, each of the two capacitors alternately charges to the peak a-c line voltage while the other is discharging through the load. Thus, their voltage rating need equal only the peak line voltage.

The ripple voltage across each of the input capacitors is equal unlike the series line-feed circuit.

It is recommended that C_1 and C_2 not be placed in the same container, since they are connected i

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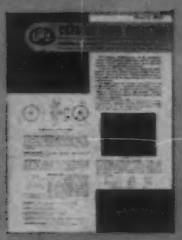

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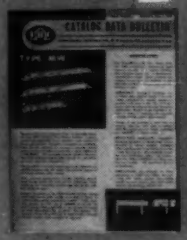

WIRE WOUND RESISTORS
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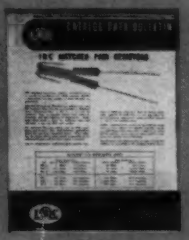
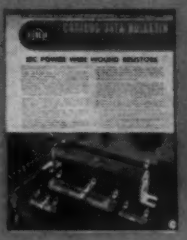


MATCHED PAIR RESISTORS



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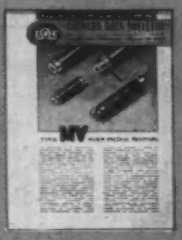

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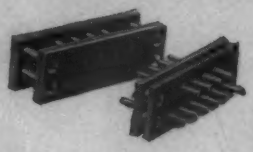

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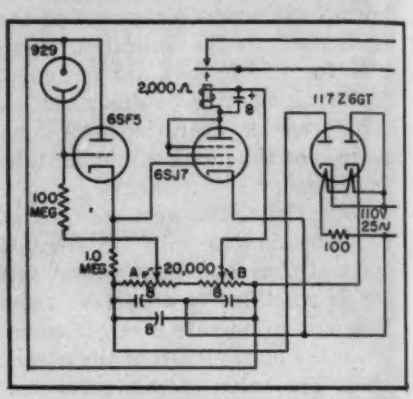
tors. This feature offers the advantage that with tube or certain other component failure, the operation of the lighting circuits is assured and areas designated to be lighted by this control will not be left in darkness.

Operation

The operating characteristics of the circuit are such that full pre-adjusted relay current is obtained above a small value of daylight intensity on the phototube. This value of daylight is adjustable to a minimum value of approximately 0.5 foot-candle. At or above whatever level of daylight to which the device is adjusted to operate, the final tube current remains constant at



Circuit of simple lighting control. Potentiometer *A* provides adjustment of input sensitivity and potentiometer *B* the relay current

the pre-set value, neither increasing nor decreasing from this value, over a wide variation in light on the phototube. Smoke from locomotives, heavy rain, fog or dense cloud formation does not cause sporadic operation of the device and time-delay circuits or mechanisms are not required.

The phototube, hooded for an angle of view of approximately 60 degrees, is mounted to obtain an uninterrupted view of the northern sky and located where extraneous light from indoors or the controlled lighting units is a minimum. The entire unit can be mounted indoors and the phototube, connected by a length of shielded cable to the amplifier, mounted on a bracket at a window or transom affording a northern exposure.

The sensitivity control is adjusted to permit drop-out of the sensitive relay armature at the

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value of daylight at which operation is desired. With full normal daylight value on the phototube, the relay current is adjusted to 5 milliamperes. With darkness, by which is meant light values below the pre-determined operating value, the output current should be checked with any extraneous light on the phototube to insure that current due to this light is not of sufficient value to pull in the sensitive relay.

Controls of this type have been applied to neon and advertising signs, unattended transformer and switching stations and street and schoolroom lighting. One unit has been successfully employed as a burglar-alarm system, using an infrared sensitive phototube and a filtered light source, and a number of them have been in continuous operation for periods as long as two years without maintenance or component replacement of any kind.

Electronic Lightning Alarm

SOUTH AFRICAN engineers B. F. J. Schonland and P. G. Gane have developed an electronism that warns of the approach of thunderstorms. The device provides two degrees of warning: (1) that lightning flashes have occurred within a radius of either 7 miles or 20 miles, depending upon the setting of a near-far

Witwatersrand gold miners are warned to store their explosives when this electronic lightning alarm sounds. It gives a short ring for each positive pulse due to a lightning flash and intermittent rings when the antenna current exceeds 2 μa. A flasher tube also operates

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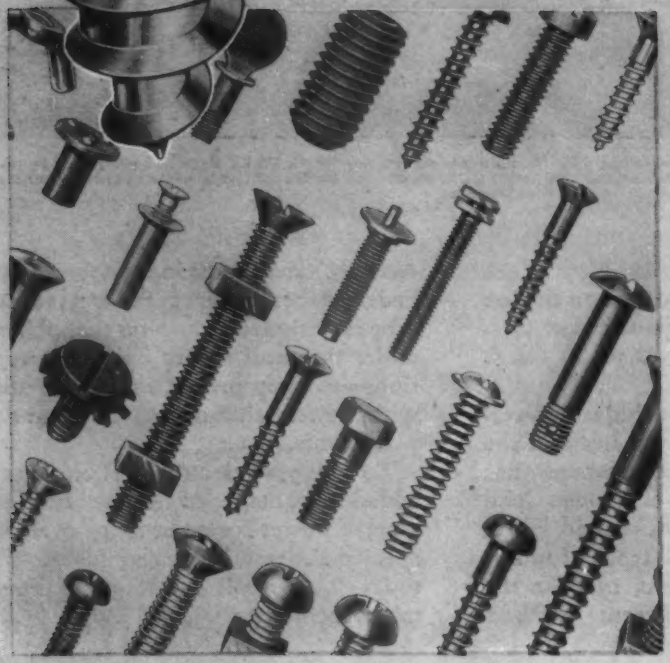


CONTINENTAL SCREW CO. New Bedford, Mass., U.S.A.

switch, or (2) that a lightning flash in the immediate neighborhood of the instrument is imminent. This lightning alarm was designed for the protection of personnel involved in the manufacture, storage and use of explosives.

The meteorological conditions on which operation of the device depends are as follows: A thundercloud carries a charge that is negative relative to ground and which produces an electrostatic field between the cloud and grounded objects. Under these conditions, a positive charge will reside on a grounded antenna in the field. When a discharge between the cloud and ground occurs, the charge on the antenna will flow toward ground. Therefore, if a resistor of suitable value is connected between antenna and ground, the flow of current from the antenna will produce a positive voltage pulse which can be used to trigger the warning device.

The average field change due to flashes which are not extremely near is of the order

$$E = \frac{9 \times 10^5}{L^3} \text{ volts per meter}$$

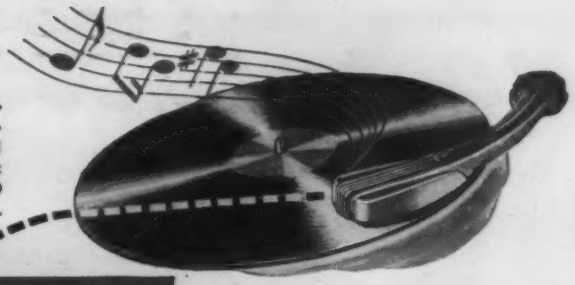
where L is in kilometers.

Another effect takes place when the thundercloud approaches close enough so that a lightning flash in the immediate vicinity can occur. This effect is the flow of corona current from the antenna to the cloud overhead. Note that the direction of flow of corona current is opposite to that of the antenna discharge current discussed above. In this instrument with the particular antenna used, corona current amounted to about 2 microamperes.

Circuit Operation

The circuit of the electronism is given in Fig. 1. The input circuits have a resistance to ground of about 0.5 megohm and are connected to the grid of V_1. The network comprising R_1, R_2, C_1, C_2 form an attenuator to reduce the transient due to a flash about 27 times when required for near sensitivity. It can be seen from the equation that this reduction in sensitivity corresponds to a reduction in range by a factor of about 3.

Tube V_1 performs two functions. It transmits transients, amplified in



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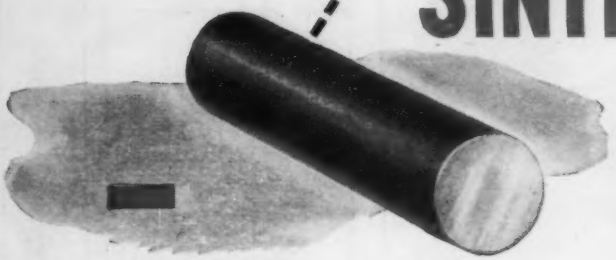

Actual size of G-E SINTERED ALNICO 5 permanent magnet used in the G-E Electronic Reproducer is shown in red.

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SINTERED ALNICO 5, General Electric's newest magnetic material, now enables you to design intricate shapes with higher external energy than ever before. The minimum guaranteed available energy is 3,500,000 gauss oersteds for most sizes and shapes. New G-E SINTERED ALNICO 5 possesses tensile properties several times those of CAST ALNICO 5 and can be produced economically in small size parts. You get better surface finish plus closer dimensional tolerances with new G-E SINTERED ALNICO 5.

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Descriptive Bulletin No. 10 Available

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BOONTON, NEW JERSEY, U.S.A.

normal fashion, via C_4 to V_2. In addition, d-c potential changes on the grid are amplified and passed via point A to V_2. Point A is tied to ground by the large capacitor C_1 which, with its associated resistors, has a time constant of about one second, and which eliminates rapid

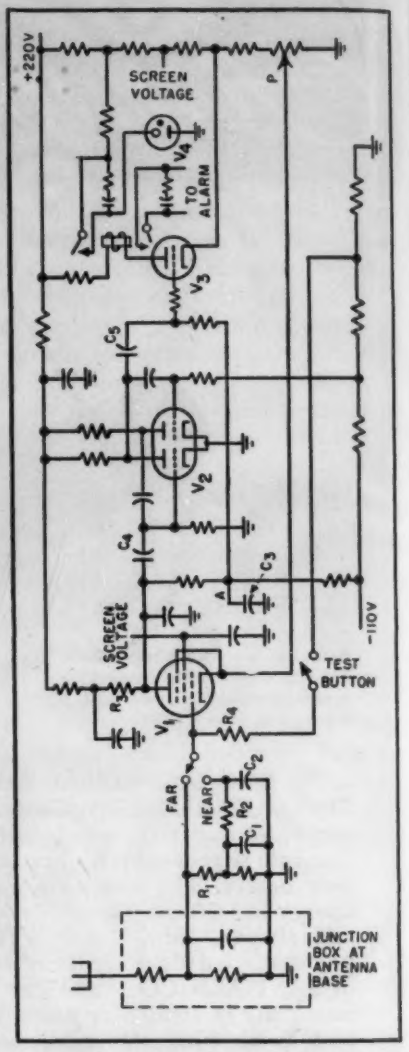


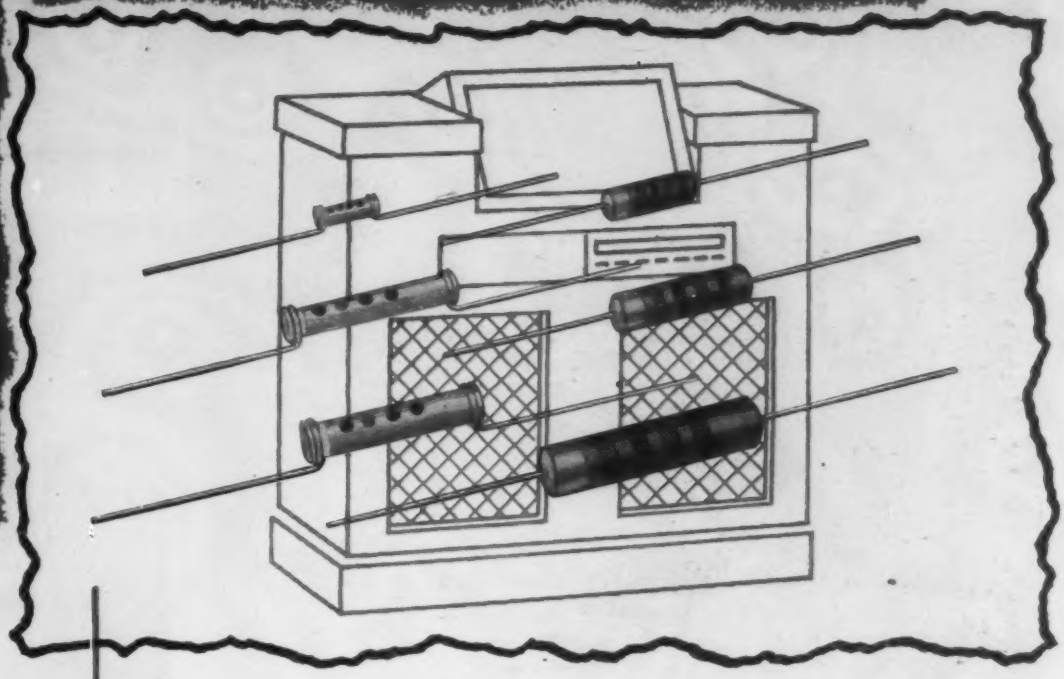
FIG. 1—Circuit of the electronic lightning alarm

signals so that the potential of A fluctuates slowly in accordance with the corona current in the antenna system.

Tube V_3 is connected in a flip-flop circuit arranged to give a positive pulse through C_5 lasting about 0.1 second. This arrangement is necessary because the transient due to a lightning flash may be too brief to operate the relay.

Bias for V_3 is obtained from point A. By means of potentiometer P the current through R_3 is so adjusted that A is at a suitable

Erie "GP" Ceramicons*



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ERIE "GP" Ceramicons are made in insulated styles in popular capacity values up to 5,000 MMF, and in non-insulated styles up to 10,000 MMF. If you are not already using them, write for detailed information.

*Ceramicon is the registered trade name of silvered ceramic condensers made by Erie Resistor Corporation.

Electronics Division

ERIE RESISTOR CORP., ERIE, PA.

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potential when no d-c is flowing in the antenna. When the grid of V_1 goes negative, the potential of A rises until V_2 conducts sufficiently to cause the relay to close. At this stage, owing to the fact that the current through V_2 is now sensitive to small changes of potential on its grid, and owing to the feedback from its cathode via

The lightning-warning antenna is omnidirectional. With the associated electronic equipment it also permits measurement of corona current

the bleeder resistors to the cathode of V_1, the whole system oscillates with a period associated with the circuits of V_2 (about 2 cps). This oscillation causes the relay to open and close periodically as long as the point A is at an adequately positive potential. It should be noted that this corona current warning is effective in either position of the near-far switch.

The instrument gives a brief sharp ring on the electric bell attached to the relays for each positive impulse due to a lightning flash, and gives a continuous intermittent ringing like that of a telephone when the direct antenna current exceeds about 2 microamperes. An additional signal is given by means of the neon tube V_4 which flashes each time the relay closes.

The operation of the instrument can be tested by means of the test button. This button applies a suitable negative voltage to the grid of

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Request Bulletin #448 for detailed information on the STABILINE Type EM and its application in the broadcast field.

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V_1 through a large resistor R_+. When the test button is pressed and released rapidly, the brief warning signal is given each time it is released. When the test button is held down for longer than a second or so then the continuous warning operates.

Antenna

The antenna consists of an unguyed vertical rod 1 inch in diameter, 8 feet high, attached to a plate at its base, which is supported by three insulators fixed at ground level. The plate keeps the insulators dry. A weatherproof junction box adjacent to the plate contains the two resistors, and from it a concentric cable is taken underground to the chassis.

By this means, any possibility of the lead-in acting as an additional antenna is avoided, and the cable capacitance becomes an essential part of the input circuit. This circuit is arranged to reduce high-frequency components in the signal such as may arise from a leader flash or from local sparks, so that the effective signal is that due to the main field change on which the rough estimation of distance depends.

This development was reported in the *Transactions of the South African Institute of Electrical Engineers*, April 1947.

Correction

Mr. T. Kite Sharpless, author of the article "High-Speed N-Scale Counters", March 1948, has pointed out an error in the footnote published in this article which gives the impression that the counters described in the article were developed while Mr. Sharpless was Technical Director of the Computer Project at the Moore School. The counters were actually developed through the joint efforts of J. Presper Eckert, Jr., John W. Mauchly, John Davis, and Frank Mural, during the period when Mr. Eckert was technical director of the ENIAC program. The Editors regret this error.

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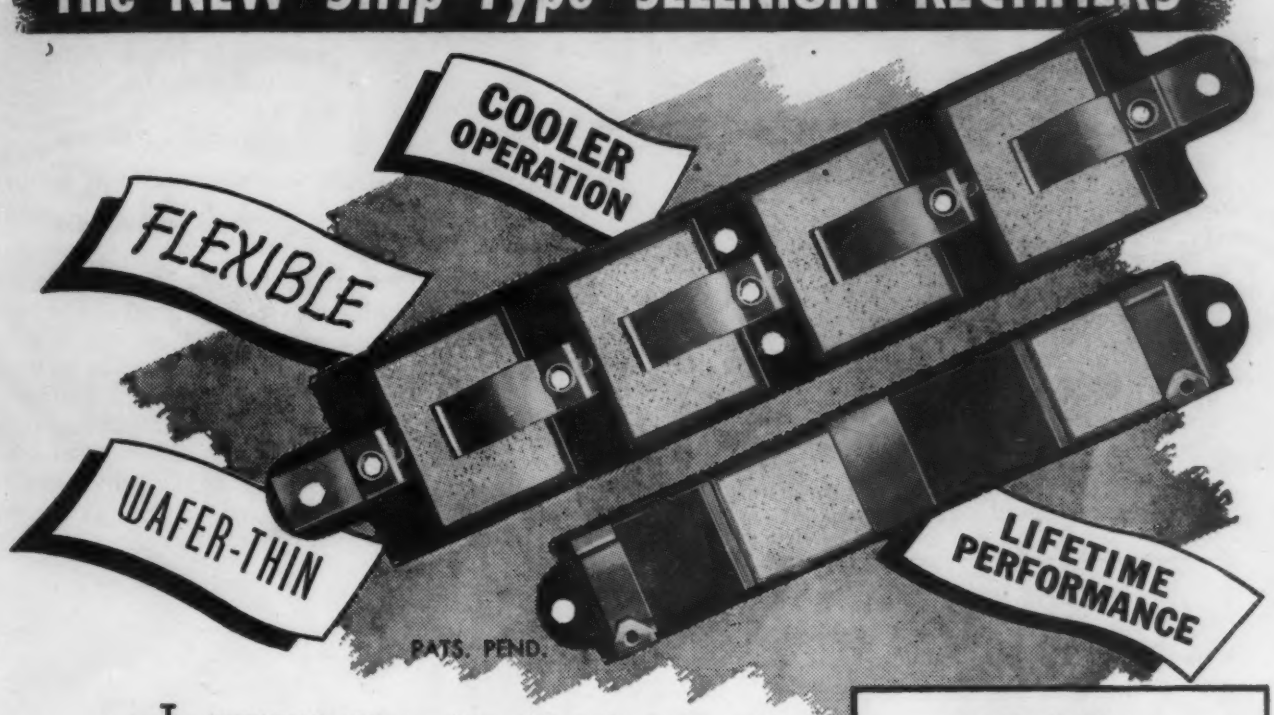

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Maximum continuous D.C. current 75 Ma.
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Average operating temperature 100 degrees F

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Maximum inverse peak voltage 360.
Maximum continuous D.C. current 100 Ma.
Maximum instantaneous peak current 1000 Ma.
Average operating temperature 105 degrees F

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Maximum continuous D.C. current 200 Ma.
Maximum instantaneous peak current 1500 Ma.
Average operating temperature 110 degrees F.

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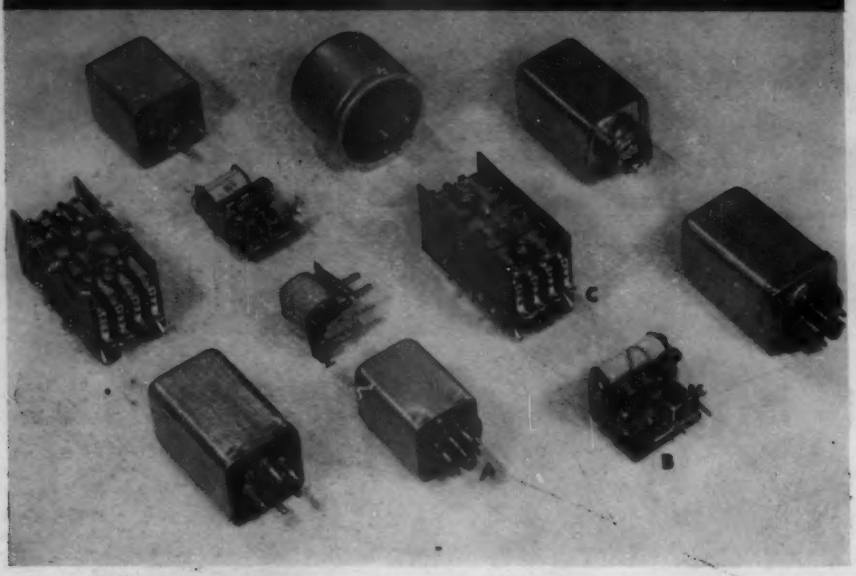

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- Contacts: Tungsten (standard) for 0.5 amp or less, moderate to high voltage, long life; fine silver for higher current, lower voltage, moderate life (e.g. 5,000,000).

Typical timing: Milliseconds

Final coil current 7.5 ma *: source	50V	100V	200V
Open N.C. contact	4 ms.	2.5 ms.	1.5 ms.
Transfer to N.O.	1.5	1.0	.7
Open N.O. contact	1.0	1.0	1.0
Transfer to N.C. (Includes Bounce)	3-5	3-5	3-5

**Sufficient external series resistance employed to limit current to this value.*

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(continued from p 134)

oscillation were obtained. Figure 3 shows typical experimental results. At frequencies where the reactances are concentrated in the tank circuit, frequency deviations of 10 percent of the mean frequency can be obtained with reasonably magnitude. Even in the uhf range frequency deviations commonly obtained at lower frequencies can be produced, so that the mean frequency can be regulated without inertia in a wide range by superimposing a control voltage on the modulating voltage.

Characteristics of Some Oil Impregnated Capacitors

By BURGESS DEMPSTER
Los Angeles, Calif.

FACTORS that ultimately control the size of capacitors operating at high voltages are primarily the internal losses. The capacitor must be large enough to dissipate the heat generated internally, without becoming dangerously hot. Because losses increase very rapidly with temperature, internal heating can become a runaway effect.

Principal Losses

There are two principal losses: (1) d-c loss in the dielectric because of leakage current, and (2) a-c loss in the dielectric because of the alternating current flowing through the capacitor. Heat generated by the first cause is equal to the square of the applied voltage divided by the insulation resistance of the capacitor. Heat produced by the second cause is equal

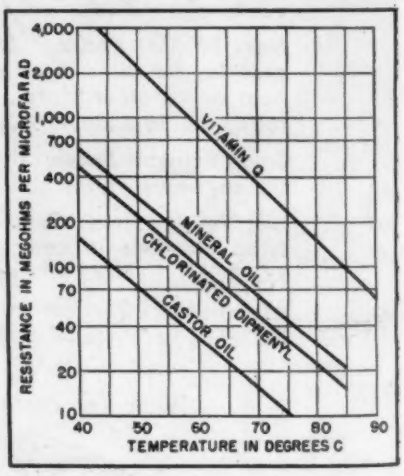

FIG. 1—Minimum insulation resistance

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to the product of the alternating current and the alternating voltage times the power factor of the capacitor. Both of these factors cause a serious amount of heat in high voltage capacitors and both increase rapidly with temperature.

Figure 1 shows the decrease of minimum insulation resistance with temperature for several types of oil. At 85 C the heating power generated in a 10 μf capacitor operating at 5,000 volts with a leakage of 20 megohms is 12.5 watts. The increase of power factor with temperature is shown in Fig. 2. Above

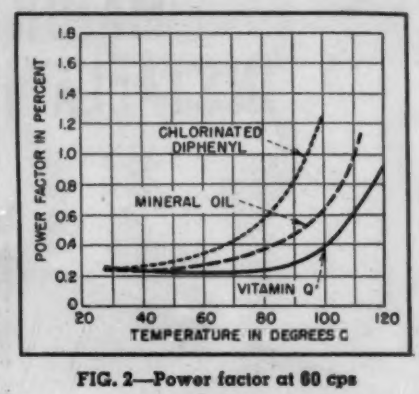


FIG. 2—Power factor at 60 cps

about 85 C the power factor of all the oils increase quickly. However, at 85 C, which is not an unusual operating temperature in many applications, the power factor of so-called Vitamin-Q, which is a synthetic hydrocarbon with great chemical stability, is only a little more than half that of mineral oil, which is the next best material in this regard. It is because of these rapidly rising losses as the temperature increases that capacitors must be derated for use at high temperatures. Figure 3 shows the derating percentages for most types of capacitors.

Because Vitamin-Q capacitors need less derating than most other types, their use in installations operating at high temperatures represents a saving in both space and weight. At 85 C the volume of a

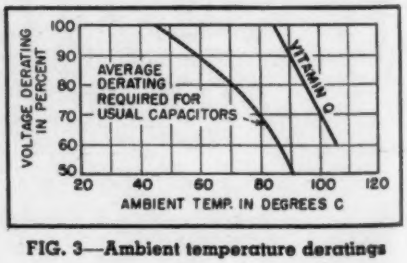
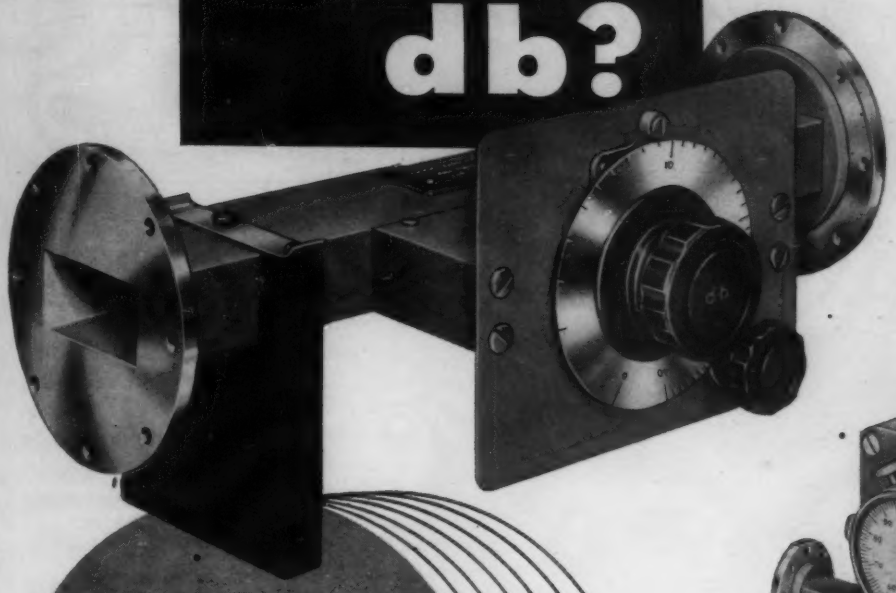


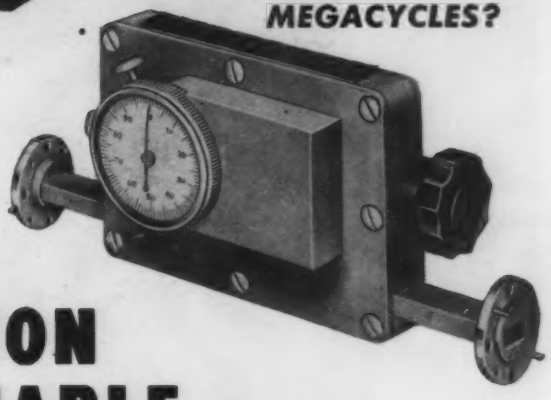
FIG. 3—Ambient temperature deratings

HOW MANY db?

..AT 5,000 MEGACYCLES?

..AT 25,000 MEGACYCLES?





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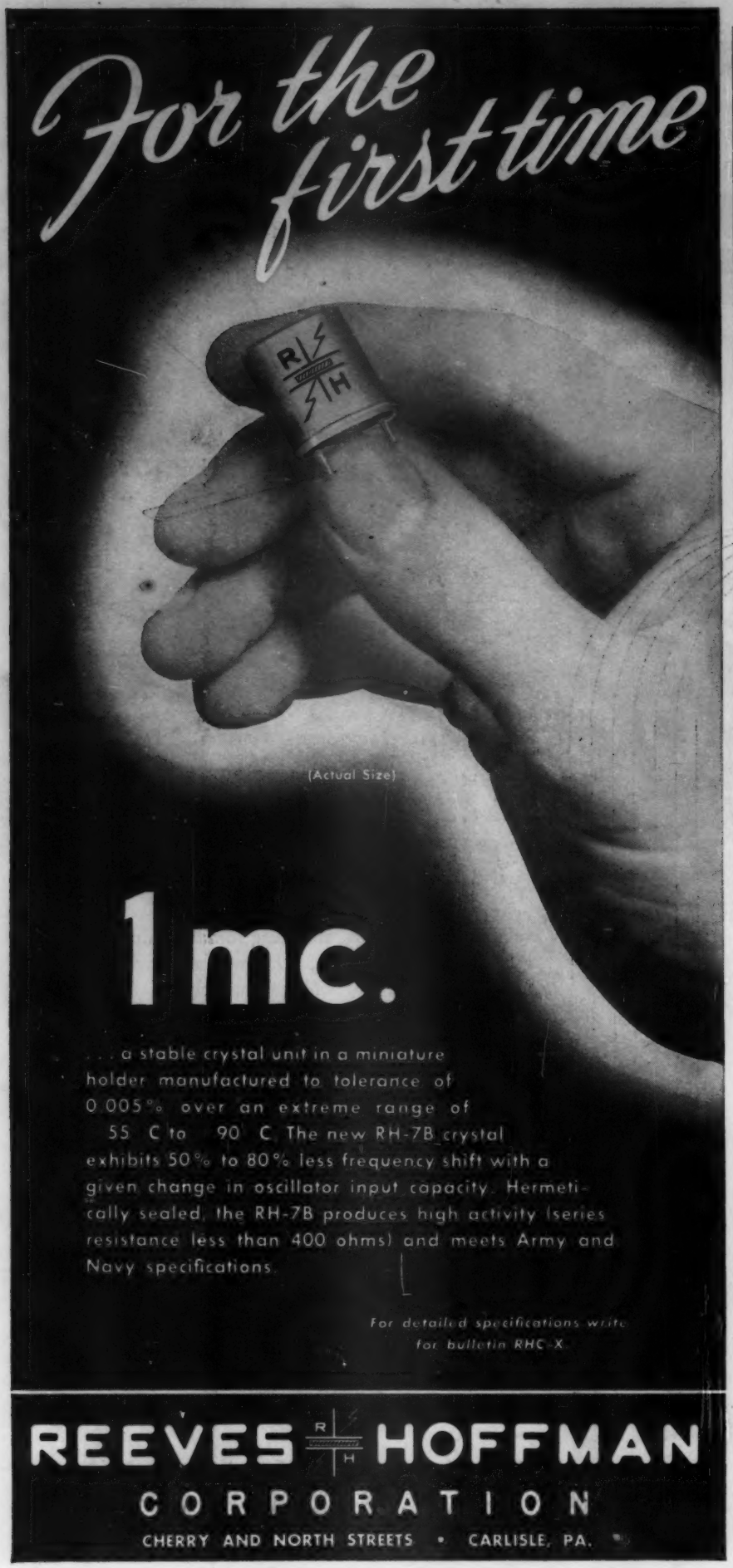
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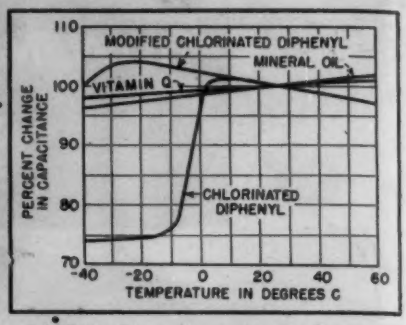

FIG. 4—Rate of capacitance change

synthetic hydrocarbon filled capacitor is only about a fourth that of a similar one with chlorinated-diphenyl, and one-sixth the size of a mineral oil unit. This characteristic is particularly important in airborne equipment, where temperatures may be high and where space and weight are at a premium.

Another important factor in choosing a capacitor for a given application is the change of capacitance with temperature, shown in Fig. 4. The rapid change of capacitance of chlorinated-diphenyl capacitors is due to the change in dielectric constant of this material. Mineral oil and Vitamin-Q are more stable in this respect. The advantages of Vitamin-Q as a dielectric are realized in capacitors rated at as low as 330 volts a-c.

One especially interesting application of capacitors where stability and high insulation resistance are important is in computing circuits. In such applications, high leakage resistance, in effect, increases the sensitivity of circuits where the final reading depends on the charge built up across the capacitor.

End Resistance Materials

By Paul G. Weiller
Industrial Engineer
New York, N. Y.

Electrical properties of nonmetallic semiconductor materials suit them for various applications. As will be explained later, the resistance of these materials appears to be concentrated mostly at their ends, hence the term "end resistance".

Possible Applications

Detailed investigation of the properties of these materials has been undertaken recently, but much remains to be learned of their behaviors. However, enough has

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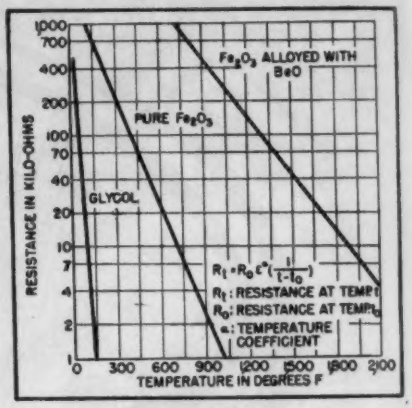
been discovered to indicate that, for example, because of their high temperature coefficient of resistance, up to five percent per degree Centigrade, they are ideal sensing units for resistance thermometers. By choosing suitable materials for particular temperature ranges as illustrated in the accompanying graph, sensitivities 1,000 times those of elements using metallic wires can be obtained. Some organic liquids have high coefficients below the ice point. Some oxide mixtures have high coefficients at room temperature, others at a few hundred degrees Centigrade. However most materials follow the relation given on the **graph.**

Some nonmetallic materials are excellent pressure sensitive devices. A small bar with a metallic coating on one end and shaped to a spherical



Measurements show that characteristics of end resistance materials change greatly with temperature

surface on the other end which bears on a metallic surface with the lightest pressure presents a contact resistance of several megohms. A weight of a gram reduces the resistance to less than a tenth megohm.

Some end resistance materials have high conductivity. If added to silver, they are suitable for long-life nonsticking electrical contacts. Similar materials can be used for electrodes in electrolytic processes, replacing carbon in many applications.

Characteristics of Matter

It is best to summarize the properties of metallic conductors to provide a background against which to describe nonmetallic conductors. In the infancy of the art, substances were classified as either conductors or insulators. Later, materials

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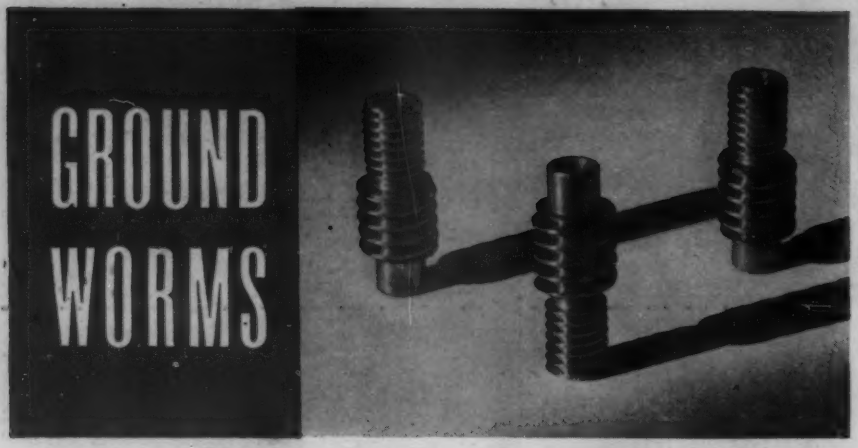

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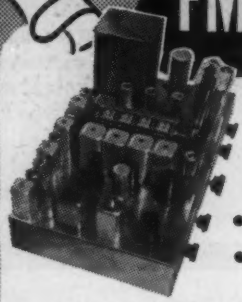

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that were intermediate between these two types were classed as semiconductors. This latter classification embraces the majority of materials.

The theory of conduction by an electronic gas describes the observed characteristics of metallic conduction quite well. Metallic conductors form a well defined class. Resistance is a minimum for the pure metals, being greater for alloys than for their constituents. In fact, small additions of other metals to a pure metal increase the resistance quite out of proportion to their quantity.

Temperature coefficients of resistance of pure metals are always positive and below one per cent per degree Centigrade; the coefficient of alloys is generally lower. Metallic conductors follow Ohm's law, the resistance of a bar being proportional to its length and inversely proportional to its cross section. That is, resistance is a characteristic of the body of the material.

Nonmetallic Conductors

The large class of nonmetallic conductors, the properties of which are only now beginning to be explored, comprises those substances with resistivities higher than metals but which nevertheless are not insulators. This group contains most of the known substances.

In measuring characteristics of about 100 organic materials and also distilled water, several effects were observed. Later the same range of properties was found in metallic oxides and their mixtures, in ceramics, and in glasses. Some of these nonmetallic conductors display erratic or unstable behaviors; others fit the general pattern, or are stable enough for practical use.

Resistance depends on the method of applying electrodes to the samples under test, and sometimes on the electrode material. If the area of the interfaces at the ends of the sample are unequal, or if the surfaces are uneven, rectification occurs, the ratio of the resistances in the two directions being a function of the ratio of the areas of the interfaces, but also depending on the electrode material. To get consistent results, the ends of the test bar must be coated with a metal that adheres to the material and

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Color	Brown	Tan	Gray
Adhesion	Good	Satisfactory	Satisfact
Penetration 77/100/5	0	0	
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Spec. Grav.	1.54	1 55	
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perhaps wets it. Resistance is almost proportional to the interface between the electrode and the bar, about 80 percent of the resistance being in the interface. For example, if the bar is broken in half and the new surface coated, the resistance of the half will be but about 90 per cent of the original resistance.

Instead of being higher, as with metallic mixtures, the resistance of mixtures of nonmetallic conductors is lower than that of the pure compounds. Thus it is possible in some cases to reduce resistivity of end resistance materials to as little as 0.00004 of its uncontaminated value.

In measuring resistivity of nonmetallic materials on a bridge, it is necessary to balance a capacitance as well as a resistance component. The material behaves as if there were substantial capacitance at the interfaces. In liquids, spurious dielectric constants of 3,000 have been observed. It is likely that dielectric constants of 500,000 observed in some ceramics arise from a similar effect.

Whether capacitance at the interface is genuine or not is unknown. However, if the end resistance material is placed across a direct potential for a short time and then switched quickly off and across a microammeter, current flow will be indicated for an appreciable interval. That the charging and discharging takes a finite period suggests that the phenomena is frequency sensitive. This assumption was confirmed experimentally.

In liquids another peculiar phenomena was observed. The resistance is affected by movement of the liquid with respect to the electrodes. Even a slow flow appreciably decreases the resistance.

Temperature coefficient of end resistance materials is generally negative. Resistance decreases at first rapidly with increasing temperature at from two to five percent per degree Centigrade, then less rapidly in the manner of an exponential curve dropping to less than one per cent at high temperatures. In one case the temperature coefficient dropped to zero and then became positive. It is however unknown whether this phenomena was due to a change in the material;

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changes in structure with temperature may account for several of the observed anomalies. Apparent capacitance also changes with temperature, but irregularly.

For accurate reproducibility of results all measurements should be made with alternating current. Many of the materials undergo electrolytic changes when exposed to direct current. It is possible that these changes do not occur below a temperature threshold, but the latter is difficult to determine with certainty. In general, d-c resistances differ from a-c resistances, but this point has not been thoroughly investigated.

A great many materials will have to be studied to find which ones are end resistors. Also, considerable correlation will have to be sought before generalizations can be made. Nevertheless, enough has been found to indicate that these materials have useful properties and that further extensive investigation is worthwhile.

Null Temperature Bridge

By E. L. DEETER
Naval Gun Factory
Naval Ordnance Laboratory
Washington, D. C.

SENSING ELEMENTS for temperature measurement must frequently be located at a distance from the indicator. When the separation is several hundred feet, thermocouples are difficult to use because the lead resistance is high compared to that of the thermocouples. In the application for which this bridge was designed, temperature of an underwater device connected to the monitoring station by a maximum of 1,000 feet of multiconductor cable was readily sensed by a high-resistance Thermistor rod. (The Western Electric type 9-A, which, for instance, is 0.9 inch long and 0.1 inch in diameter, has a resistance at 25 C of about 32,000 ohms.) In comparison, the resistance of the No. 20 B & S cable conductor is small, and its temperature coefficient can be neglected entirely if a dummy resistance equal to the nominal cable value is included when the bridge is calibrated.

Indicating Circuit

Figure 1 shows the Wheatstone bridge, one leg of which includes

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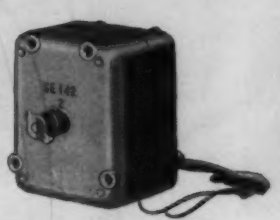

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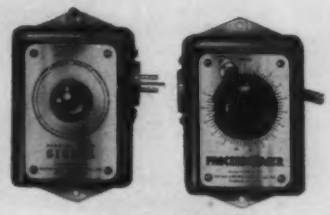

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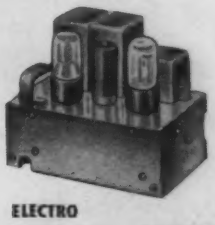

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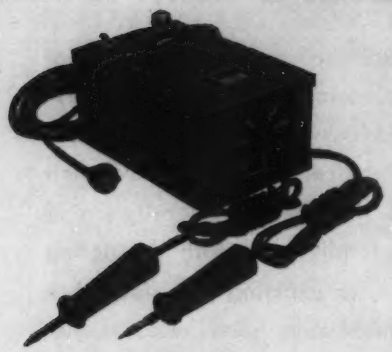

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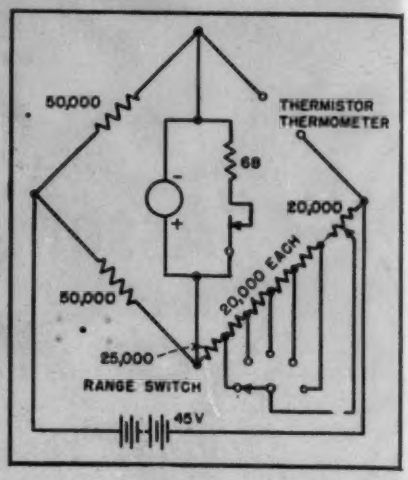

FIG. 1—Circuit of temperature bridge

the Thermistor detector. After the Thermistor detector is connected and the on-off switch is closed, the selector switch is set to one of five positions to bring the meter near to zero. The 20,000-ohm potentiometer is then adjusted to bring the meter needle within one division of zero before pushing the button that removes the meter shunt. The final balance position of the large potentiometer dial, at full meter sensitivity, is referred to one of the five calibration charts to obtain the temperature indication.

There are 14 inches of graduation on the large dial. The total temperature range is divided into 5 scales, so that 70 inches of scale are obtained. The instrument is used for a temperature range from 32 to 102 F, or a spread of 70 F. Thus there is a mean of one inch of scale per degree Fahrenheit. The scale can be read easily to within 2 percent of a degree. The accompanying photograph shows the construction of the bridge and positions of the controls.

The resistance-temperature curve of the Thermistor used is shown in Fig. 2. Because of the flattening at the cold end, a 500,000-ohm shunt is connected across the Thermistor terminals at the bridge when the selector position is in position 5. With this arrangement (not shown in the circuit), the bridge covers a 10-degree range in the cold position.

Battery drain is small, the battery life being several months even under constant use. Decay in battery voltage does not affect the accuracy of the bridge. The 20,000-ohm potentiometer (General Radio

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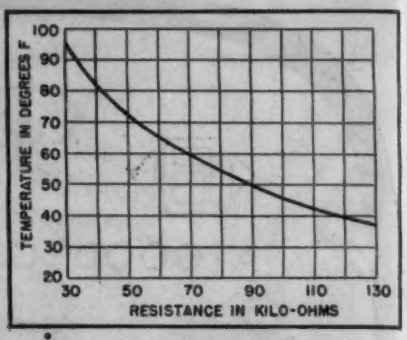

FIG. 2—Characteristic of Thermistor

314-A) is always a fraction of the leg resistance, so smooth control is obtained. Precision resistors are used throughout.

After the bridge was completed, a 50,000-ohm resistor was placed across the Thermistor terminals and the bridge balanced on the sensitive position. The unit was then placed in a controlled cabinet and the temperature varied between 30 and 140 F. The movement of the meter needle was barely perceptible, indicating that the operating temperature of the bridge does not interfere with the indication.

Sensing Element

The Thermistor should be protected against surface leakage when used in a humid atmosphere. Two types of housings were made. For immersion in water, a thin-walled nickel-plated brass cylinder filled with Toluene is used. For checking temperature in a cold atmosphere, a thin-walled brass tube with fins and containing dry air is used. The main consideration in constructing the housing is thermal conduction between the medium to be checked and the sensing element.

Thermal time constant, which is the exponential coefficient of the law of cooling for a body at a different temperature from that of its surroundings, is the time required for the Thermistor to change 63 percent of the difference between its initial level and that of its surroundings, if no electrical power is being dissipated in the Thermistor. The detectors just described have thermal time constants of about 155 seconds.

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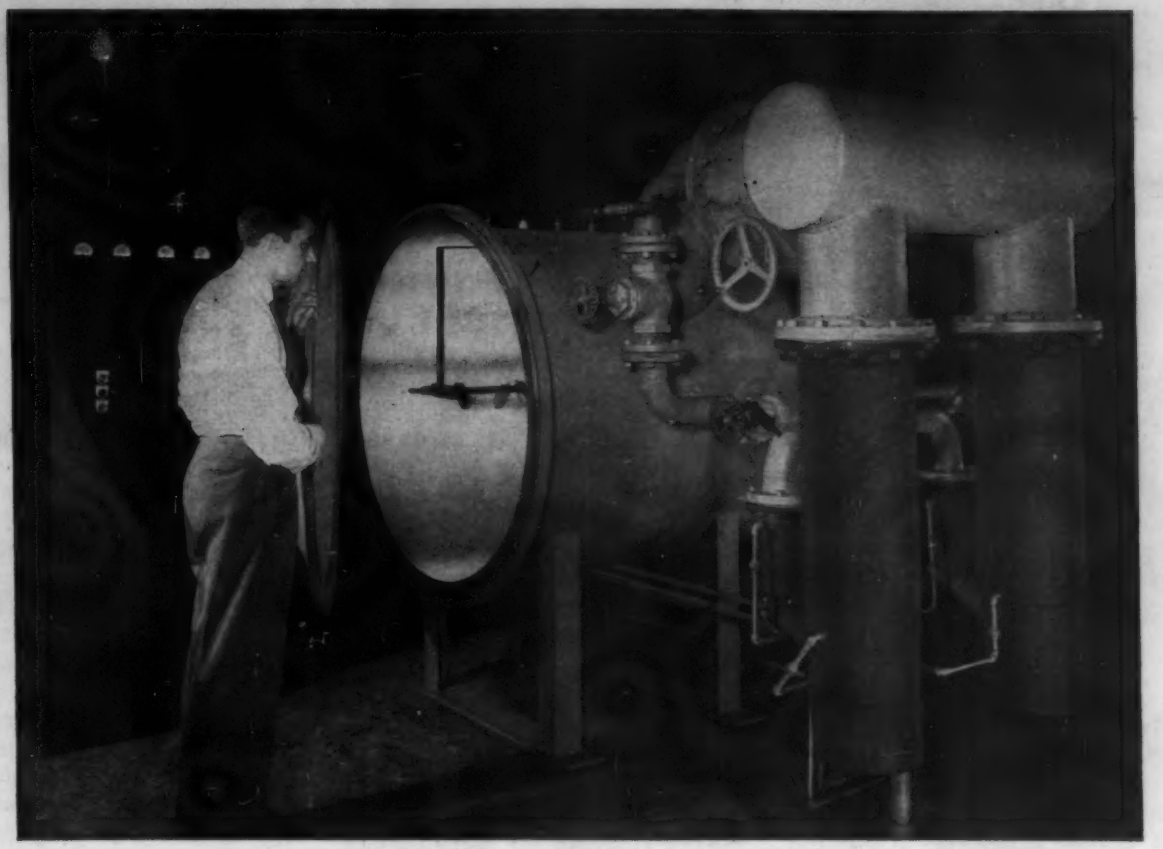

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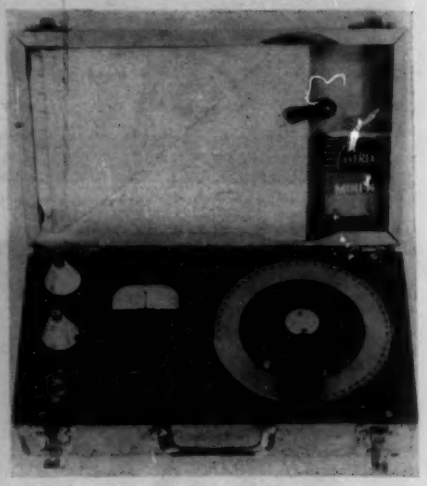


Carrying case for bridge consists of two plated steel chassis hinged bottom to bottom

a year. This change corresponds to about 0.05 C in this bridge.

Some early Thermistors, when used in this bridge, produced a hysteresis loop. A continuous line could be obtained as the temperature was increasing or decreasing, but when the direction of temperature change was reversed, a new parallel line was followed. If the temperature change was stopped at any point and later resumed in the original direction, the line was a smooth continuation. However, three Thermistors of the type used in this bridge were picked at random and given cycling tests totaling around 150 hours, over a period of three months. Over the temperature range that this bridge was designed to cover, their stability was very good and no hysteresis or fatigue was evident. The thermal lag was consistent with the time constant.

SURVEY OF NEW TECHNIQUES

SPACER COMBS FOR TUNING CAPACITORS made of Nylon have reduced rejects on the production line, and also make the capacitor less subject to damage in use. In adjusting assembled variable capacitors it is necessary to move the plates slightly. Spacers made of conventional brittle materials frequently break during adjustment, resulting in the entire unit having to be scrapped. Although Nylon combs, made by The Polymer Corp., are 5

Permanent Magnets do it Better in *Magnetic Separators*

For removing ferrous particles from:

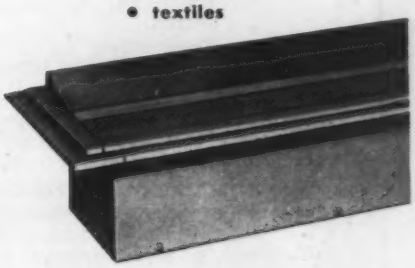
- coke and coal
- fertilizers
- chemicals
- ceramics
- rock products
- foods
- liquids
- plastics
- textiles

To assure the correct magnetic pull for their complete range of tramp iron separators, Eriez Manufacturing Co., Erie, Pa., requires many different types of magnets. Our engineers designed special *permanent* magnets for the entire Eriez line, bringing *high efficiency* and *low cost* to the removal of ferrous particles from such diverse materials as air, liquids, coal, and rock products. Materials and processing equipment *in many industries* are now protected by Eriez job-fitted separators using *Indiana Steel* permanent magnets.

Only permanent magnets offer these advantages:

1. Steady, everlasting strength.
2. No wiring or electrical current needed.
3. Minimum installation cost.
4. No operating cost.
5. Cool running—no temperature effects.
6. Not affected by moisture.
7. Easily installed in original equipment.
8. Uninterrupted operation.

Perhaps *you* have a job that permanent magnets can do better. Our forty years' experience in permanent magnets and our exceptional design service are at your call. A discussion with our engineers may develop unexpected savings and increased efficiency in your product. Write for complete information.



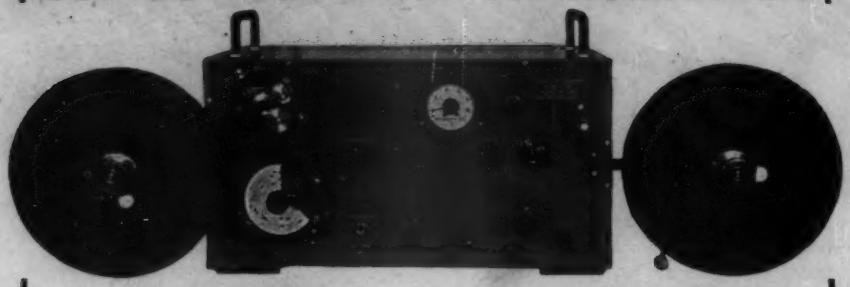
Eriez "Giant" Magnetic Separator
The largest Alnico magnetic separator produced

THE INDIANA STEEL PRODUCTS COMPANY

PRODUCERS OF "PACKAGED ENERGY"
6 NORTH MICHIGAN AVENUE • CHICAGO 2, ILL.
SPECIALISTS IN PERMANENT MAGNETS SINCE 1910

PLANTS { VALPARAISO, INDIANA
CHAUNCEY, N. Y.

Mecanitron Presents
the New and Versatile
SCP-25 SCANNER TRANSMITTTER



Mecanitron SCP-25 converts Morse or teletype characters originating on inked slip into electrical equivalents. It has a wide variety of uses on radio telegraph circuits.

TWO types of scanner head are supplied with the SCP-25. Known as the SH-4 and SH-5, they can be instantly interchanged.

. . . The SH-4 Scanner Head — a complete photo-electric unit. It will accurately scan any tape on which any shade of blue or black ink is used.

. . . The SH-5 Scanner Head— uses the conduction principle in a completely contained unit. When the use of conducting ink on tape is desirable, the SH-5 Scanner Head reproduces an extremely accurate grade of copy. The SH-5 is easily adapted to scan *three* separate and distinct messages originating on a standard ⅜" slip. Scanning is accomplished either *alternately* or *simultaneously*.

. . . The 15-tube electronic circuit offers the following features:

1. High impedance, bridge-type input circuit.
2. Three-stage, phase-inverted DC amplifier with screen grid feedback to produce controlled, trigger-action.
3. RC coupled, constant-amplitude tone generator, operating from 800 to 3000 cycles, feeding a transient, free-balanced modulator output circuit.

. . . The following outputs are available:

1. On/off direct current up to 80 milliamps with phase-reversing switch.
2. Polar DC up to 40 milliamps with phase-reversing switch.
3. Tone output up to 14 VU with phase-shift switch, output impedance 500 ohms.

. . . Tone is available either alternately or simultaneously with other outputs. DC outputs are suitable for direct connection to existing teletype printers. Individual voltage regulators provided for all circuits.

. . . Speed Control— SCP-25 is available complete with Mecaniclip take-up and storage reels and the famous Mecanitron YY-2 Tape Puller featuring constant, pre-set speeds accurately calibrated in a continuous range from six feet to 148 feet per minute.

YOUR BEST BET FOR INCREASED TRAFFIC ON HIGH-SPEED RADIO, TELETYPE OR MORSE CIRCUITS IS THE SCP-25 COMBINED WITH THE INTERNATIONALLY FAMOUS MECANITRON HIGH-SPEED RECORDER, MODEL MA-126.

Write for additional information today!

MECANITRON CORPORATION

General Offices: **8 Irvington Street, Boston 16, Mass.**

Phone: COmmonwealth 6-2639

BRANCHES: 1011 New Hampshire Avenue, Washington 7, D. C., Phone: NAtional 0310
142 Bank Street, Ottawa, Ont., Canada, Phone: Ottawa 5-5590

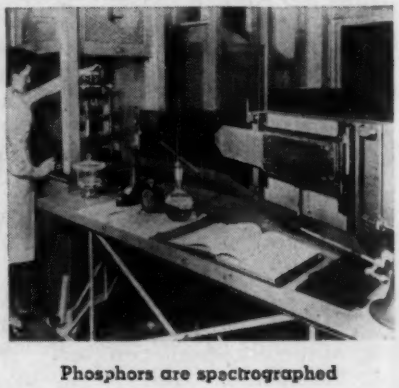
to 10 percent costlier than conventional combs, the reduced breakage is great enough to absorb a 500 percent increase in cost of material. Expansion of the combs due to moisture absorption compares with that of other plastics.

DESIGNED FOR LABORATORY and industrial research, a universal oscilloscope, shown at Brettenham House, London, presents five traces

Six-inch crt presents five traces

simultaneously. Units of the equipment are interchangeable; plugging facilities make possible addition to other units to adapt the oscilloscope to future developments.

LUMINESCENT MATERIALS for cathode-ray tubes are vaporized in a 4,400-volt a-c arc for spectrographic analysis of their characteristics at North American Philips Labs. This



Phosphors are spectrographed

type arc is stable and results in low background on the spectrum plate. Results of the spectrographic investigation will provide background data for designing television picture tubes.

ONLY PHILLIPS CROSS RECESSED HEAD SCREWS

ARE ENGINEERED FOR PRACTICAL PRODUCTION DRIVING

RECESS EDGE ROUNDED AT TOP

Prevents pushing up burrs because contact with driver begins just below top surface of screw head. Easy for driver to "ride in" to a firm seat, without excess strain on driver point wings.

WIDER OPENING AT RECESS CENTER

Absence of sharp corners provides wider center opening. This recess shape aids self-centering of driver. It also permits driving tool contour that insures maximum strength.

RECESS WALLS HAVE MINIMUM TAPER

Steep walls resist tendency of driver to ride or "cam" out of recess. Consequently, less end thrust is needed at any torque. Driver seats fast - stays seated.

LOOK CLOSELY at the Phillips Recess. No sharp corners to burr easily — require slowed-down, fussy starting — or to "beat up" bits.

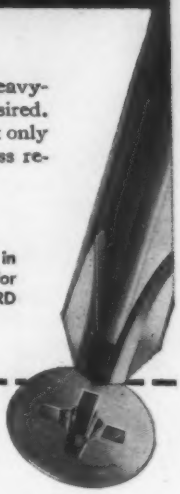
Phillips Engineers shaped this recess according to job conditions, not on abstract theory. They know assembly workers are fast moving, often "heavy-handed," cannot always be as fully trained as desired.

That's why Phillips Recessed Head Screws not only promise, but *deliver* all advantages of the cross recessed head on any assembly job.

GET ALL THE ADVANTAGES OF ASSEMBLY WITH CROSS RECESSED HEAD SCREWS . . . GET

GET THIS NEW BOOKLET to guide you in selecting the right cross recessed head screws for your assembly . . . "Why Phillips is the STANDARD Cross Recessed Head Screw". It's free.

USE THE COUPON



PHILLIPS *Recessed Head* SCREWS

Wood Screws · Machine Screws · Self-tapping Screws · Stove Bolts

25 SOURCES

American Screw Co.
Central Screw Co.
Continental Screw Co.
Corbin Screw Div. of American Hdwe. Corp.
Elco Tool & Screw Corp.
The H. M. Harper Co.
Lamson & Sessions Co.
Milford Rivet and Machine Co.
National Lock Co.
National Screw & Mfg. Co.
New England Screw Co.
Parker-Kalon Corporation
Pawtucket Screw Co.
Pheoli Manufacturing Co.
Reading Screw Co.
Russell Burdsall & Ward Bolt & Nut Co.
Scovill Manufacturing Co.
Seaboard Screw Corp.
Shakeproof Inc.
The Southington Hardware Mfg. Co.
The Steel Company of Canada, Ltd.
Sterling Bolt Co.
Strongpoint Screw Products, Inc.
Wales-Beech Corp.
Wolverine Bolt Company

Phillips Screw Mfrs.,
c/o Horton Noyes Co.
1800 Industrial Trust Bldg.
Providence, R. I.

Send me the new booklet — "Why PHILLIPS is the STANDARD Cross Recessed Head Screw". E-27

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Company .....

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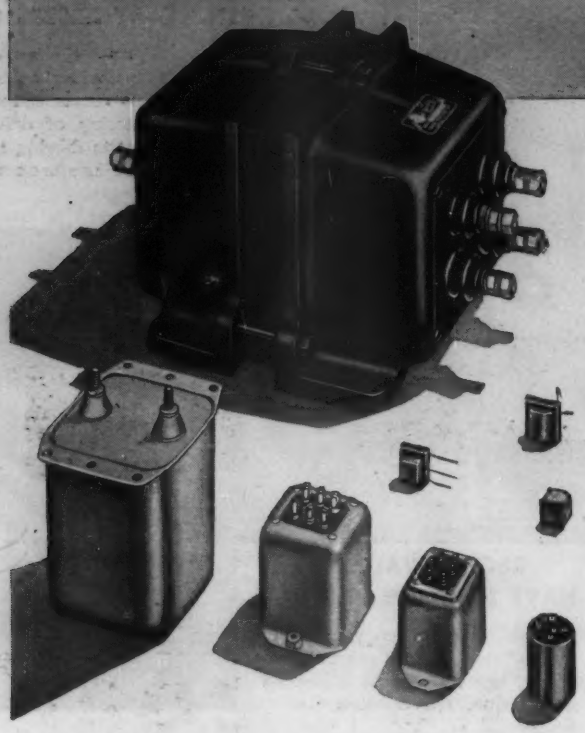
SPECIFIED PERFORMANCE
PROMPTLY DELIVERED!

Insist Upon Genuine

STANCOR
TRANSFORMERS



STANCOR has the ability to meet the most exacting demands for all specialized transformer needs . . . expertly . . . immediately. The combination of superior engineering, streamlined plant facilities and mass production unite to guarantee transformers that will give you the utmost in efficiency—at the lowest cost to you.

Our Competent and Versatile Engineering Staff Is Available Now to Meet Your Most Exacting Transformer Requirements . . . Write or Wire Us Today.

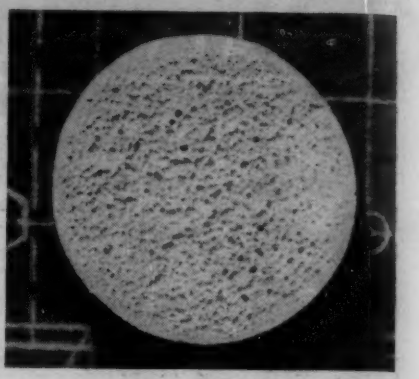
STANCOR

STANDARD TRANSFORMER CORPORATION
ELSTON, KEDZIE & ADDISON • CHICAGO 18, ILL.

effect of light viewed through an aperture in the turbine disc.

Silicone Sponge

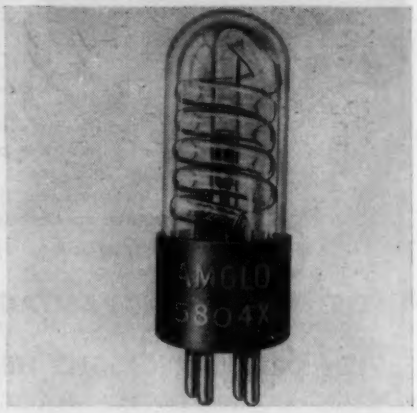
CONNECTICUT HARD RUBBER CO., 407 East St., New Haven 9, Conn. Silicone rubber sponge for sealing and



vibration damping can be used in the temperature range from 500 to minus 70 F. It is available in extruded shapes, sheets, or as molded items.

High Speed Flash

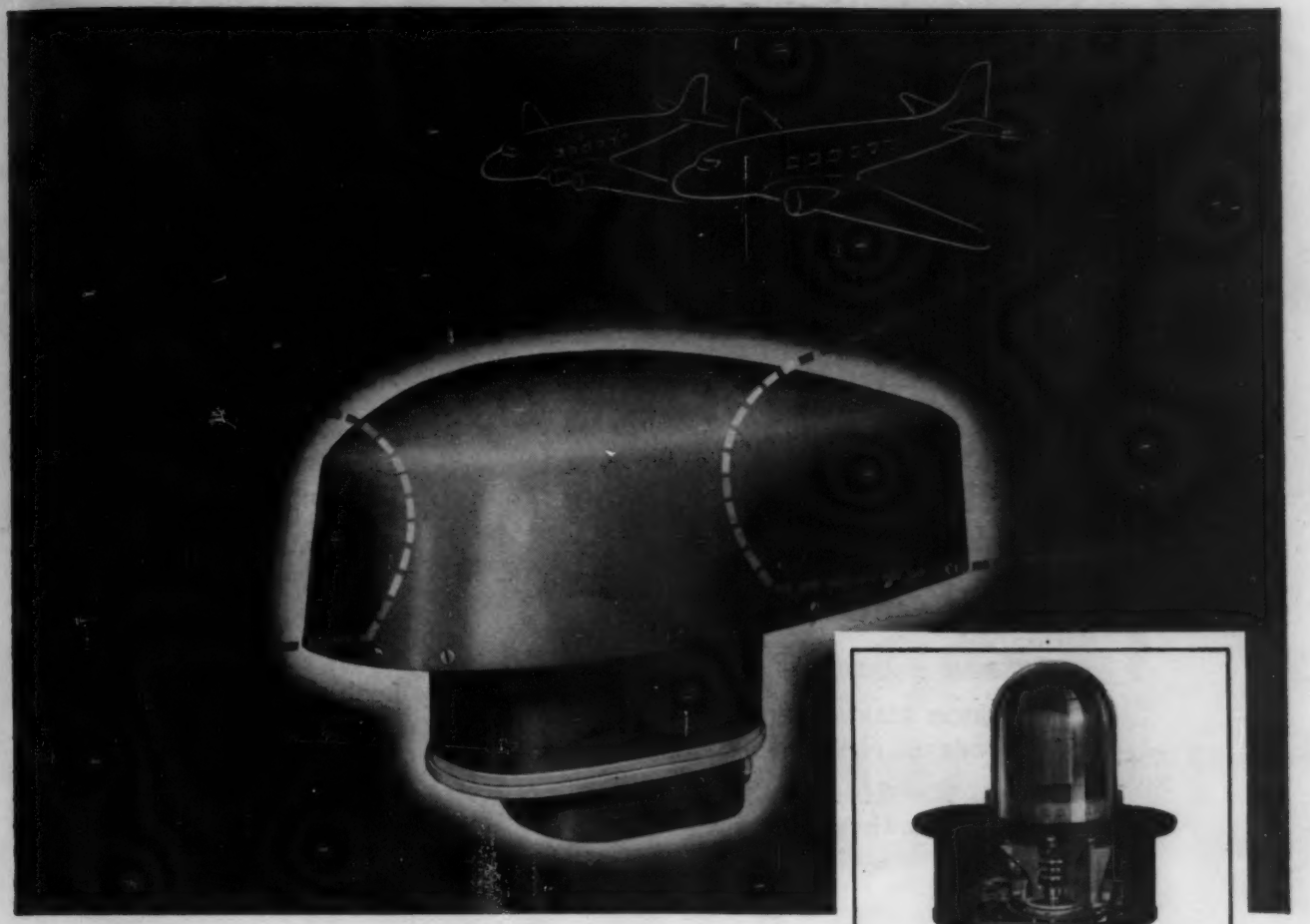
AMGLO CORP., 4234 Lincoln Ave., Chicago 18, Ill. Amglo 5804X lamp has a peak lumen output of approximately 40 million. Maximum en-



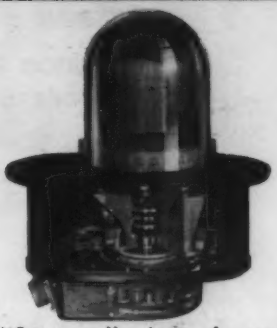
ergy input is 100 watt-seconds with recommended operating voltage between 2,250 and 2,850 volts. It does not require an auxiliary high voltage pulse to initiate ionization.

R-F Oscillator

TECHNICAL INSTRUMENT CORP., 1058 Main St., Waltham 54, Mass. Type



The new, smaller Bendix Iron Core Loop shown here, superimposed in proper proportion on the outline of the air core type that it replaces, is visual evidence of reduction in size accomplished by the use of Stackpole Iron Cores. Air drag is reduced 72% because of this more efficient loop.



"Cut-away" view of new Bendix Automatic Loop Antenna. Note iron core in upper cutaway portion of hermetically sealed unit.

STACKPOLE IRON CORES *REDUCE AIR DRAG 72%*

Unusual as it may seem, careful research and modern electronic design has shown that the use of Stackpole Powdered Iron Cores increases the pay load of regular commercial aircraft.

The new Bendix Automatic Loop Antenna as used in Bendix Radio Division's Navigational System is smaller in size and more efficient than the air loop it replaces. Stackpole Iron Cores permit this reduction in size and also increase the efficiency of the loop. Air drag, an all important consideration in aircraft design, is one of the determining factors in establishing the allowable "Pay Load." Air drag at 250 mph, *has been reduced by more than 72%* by use of this new Bendix loop!

Stackpole Powdered Iron Cores are performing miracles like this for many other manufacturers, too. Improved performance, reduced costs, smaller physical sizes—these are some of the advantages that usually result when Stackpole Iron Cores are designed into inductive circuits. *Write on your company letterhead today for full information.* Ask for STACKPOLE Bulletin No. RC7B.

STACKPOLE CARBON COMPANY, ST. MARYS, PA.

STACKPOLE

IRON CORE HEADQUARTERS

Present 3 clean-cut Advantages

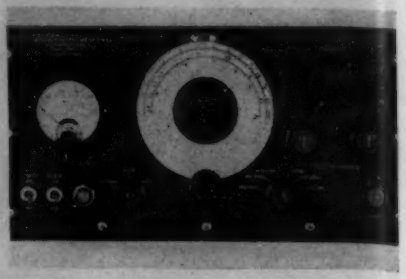
1. **EXTREME UNIFORMITY**
2. **SUPERIOR STAKING QUALITIES**
   . . . ends will roll without splitting.
3. **BETTER FOR MOLDED PARTS**
   . . closed end keeps compound out.

If you use pins for vacuum tubes, adapters, fluorescent lamps, plugs, or electrical equipment of any kind, the chances are you'll save time, money and rejections by using these super-smooth, *seamless,* patented Radio Pins. They are available in a wide variety of styles and sizes, with staking end either closed or open. For a quotation, simply send a sketch, sample or description and state the quantity you need.

Radio or Radar Equipment?

In addition to Radio Pins, we produce large quantities of top caps, base shells and adapter shells for vacuum tubes; also a wide variety of other metal products including deep drawn shells and cups, blanks and stampings, ferrules, grommets, washers, vents, fasteners—and, for almost every manufacturing requirement, the world's largest assortment of eyelets. 47420

THE AMERICAN BRASS COMPANY
Waterbury Brass Goods Branch
General Offices: Waterbury 88, Connecticut
Subsidiary of Anaconda Copper Mining Company
In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*



410-A r-f oscillator is a general purpose laboratory instrument and a signal source for r-f bridges. It is provided with output voltmeter and a continuously adjustable level control. Frequency range is 100 kc to 10 mc in six bands. Internal modulation at 1,000 cycles is provided. Output impedance is approximately 50 ohms.

Leak Detector

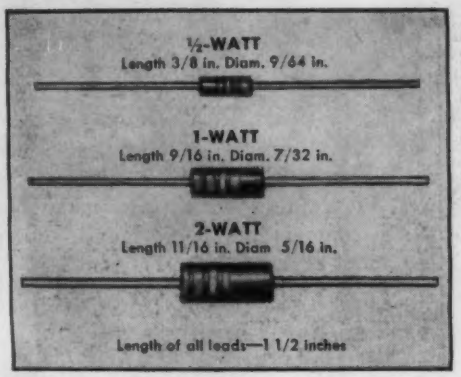
GENERAL ELECTRIC CO., Schenectady 5, N. Y. A new portable leak detector designed for production testing of hermetically sealed units in which halogen compounds are used as refrigerant will detect a

leak so small that it will release only 1/100 ounce of Freon per year. Detector unit weighs 3 pounds and the control unit 15. Earphone or loudspeaker indication is provided as well as a meter deflection. Bulletin GEC-233 tells more.

Micrometer

STEVENS-ARNOLD INC., 22 Elkins St., South Boston 27, Mass. A new electric micrometer can be used for measuring, gaging, comparison, and telemetering up to 100 feet. The equipment comprises a control unit with zero-center meter and a transmitter with plunger that will accept motion of plus or minus 0.010 inch

ANY RESISTANCE-ROTATION CURVE



ALLEN-BRADLEY FIXED RESISTORS

Bradleyunit solid-molded, fixed resistors are not rated on the basis of the conventional 40C ambient temperature . . . instead, they are rated at 70C ambient temperature. They will operate at full rating for 1000 hours in an ambient temperature of 70C with a resistance change of less than 5 per cent.

The ½-watt and 2-watt sizes are available in standard R.M.A. values from 10 ohms to 22 megohms. The 1-watt size from 2.7 ohms to 22 megohms.

Such "extra" performance guarantees dependability for your electronic equipment.

The Type J Bradleyometer can be built to produce any resistance-rotation curve because, during manufacture, the solid-molded, ring-type resistor can be varied in resistance throughout the circumference of the ring.

It is not a film- or paint-type resistor. The resistor unit is molded as a one-piece ring with terminals, face plate, and threaded bushing imbedded in the molded piece. After molding, the resistor material is no longer affected by heat, cold, moisture, or age. The contact brush actually improves with age.

In the Type JW Bradleyometer a resilient, watertight packing is placed around the shaft to exclude moisture.

Type J Bradleyometers can be supplied in single-, dual-, or triple-unit construction for rheostat or potentiometer applications. A built-in line switch is an optional feature on single and dual models. Specifications sent upon application.

Allen-Bradley Co., 110 W. Greenfield Avenue
Milwaukee 4, Wisconsin

A-B Quality

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

QUALITY

MOSINEE PAPER MILLS CO.
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MOSINEE

"More than Paper"

In the field of electronics and the electrical goods industry, MOSINEE stands for paper-base processing materials with scientifically controlled chemical and physical properties, high quality standards and dependable uniformity... with good dielectric strength, high tensile or tear strength; proper softness or stiffness; creped with controlled stretch or flexibility; specified pH for maximum-minimum acidity or alkalinity; accurate caliper, density, liquid repellency or absorbency . . . or other technical characteristics vital to your quality standards and production requirements.

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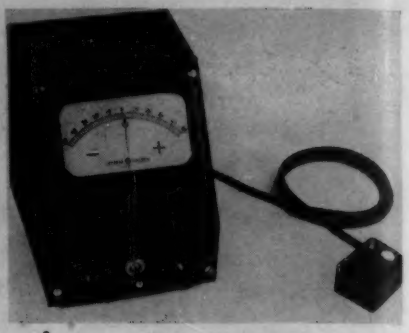


from the center position or a total of 0.020 in one direction.

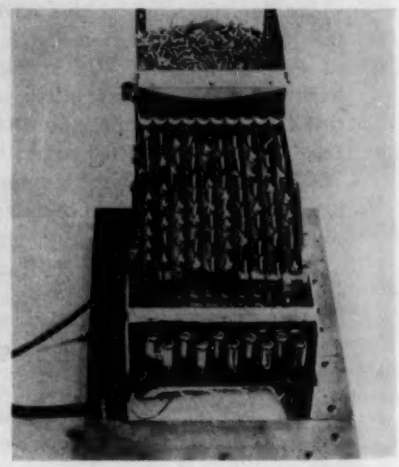
Miniature P-A Pentode

RADIO CORP. OF AMERICA, Harrison, N. J. Type 6AR5 is a new miniature power amplifier pentode in-

tended for use in the output stage of automobile and a-c operated receivers and within its maximum ratings is the performance equivalent of type 6K6-GT.

Ten-Eye Counter

POTTER INSTRUMENT CO., INC., 136-56 Roosevelt Ave., Flushing, N. Y. Counting of small parts is accom-



FEATURES AND SPECIFICATIONS

1 EQUIPMENT. Designed to give any power output in multiples of 20 watts, i.e. two driver units will give 40 watts, three driver units will give 60 watts, etc. Push-pull output tubes for adequate economical power output to drive one or two speakers. Additional driver stages available to drive any number of speakers. Note: We do not, however, carry a stock of panels or racks for purposes of installation.

2 GAIN. Adjusted for crystal pickup, adequate to allow the use of variable reactance pickup and low sensitivity microphone.

3 HUM. Less than .5 microwatts at 1 watt level—so low as to be inaudible in a quiet room with the ear 12 inches from the speaker.

4 POWER OUTPUT. Uniform within plus or minus 1.25 db from 40 to 20,000 cps at the 20-watt rating.

5 ACOUSTICAL RESPONSE. With a properly selected loud-speaker system, the equipment will produce a 20 to 20,000 cycle response.

6 NEGATIVE FEEDBACK of 8 db is incorporated. This reduces any tendency for distortion and hum.

7 PHONO INPUT. When the phono input is used, the pre-amplifier is adjusted for use with a crystal pickup. However, the separate stage of amplification provided in the MICROPHONE circuit allows a low output pickup (variable reluctance type) to be connected here without requiring additional amplification. A simple equalization network comprising resistance and capacitance is required, of values depending on the characteristics of the pickup selected.

8 TWO OUTPUT IMPEDANCES of 8-16 ohms are available to match several speaker arrangements.

9 BUILT-IN DYNAMIC NOISE SUPPRESSOR uses 4 tubes incorporating three gate circuits, all dynamically controlled. Two circuits control the high frequency, wide band response, and one controls the low frequency, narrow band response. The high frequency and low frequency responses are individually controlled from two separate circuits incorporating individual voltage and timing constants. Five positions of control are provided: two for noisy records, one for the off (or disconnect) position, and two for records that need noise suppression only at times. When the volume level of the record is such that the scratch might be apparent, the dynamic action will automatically allow the reproduction of all the tones to be heard in the acoustical system. The bass gate works the same way, protecting against any rumble or low frequency noises.

10 FIVE CONTROLS for simplicity:

a. Full range volume control.
b. Bass control continuously variable. A total variation of 28 db at 100 cps allowing for individual choice of bass boost or cut.
c. Treble control continuously variable. A total variation of 25 db at 5000 cps allowing for individual choice of treble boost or cut.
d. Selector control selecting the choice of inputs.
e. Music control giving the choice of the degree of suppression of noise or the expansion of the tonal range when the noise components are not objectionable.

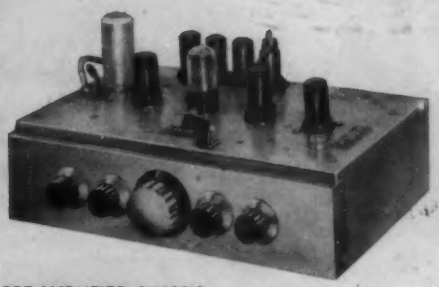
11 TUBE COMPLEMENT

1 6SJ7	Microphone or high gain pre-amplifier
1 6B8	Noise amplifier and diode gate control voltage rectifier
1 6SG7	High frequency sharp cut-off gate control tube
1 6SG7	High frequency control tube
1 6SJ7	Bass frequency control tube
1 6SJ7	First audio amplifier tube
1 6SL7	Tone control tube
1 6J5	Second audio amplifier tube
1 6J5	Third audio amplifier tube
1 6SN7GT	Phase inverter and driver tube
2 6L6G	Power output tubes
2 5Y3	Voltage rectifiers.

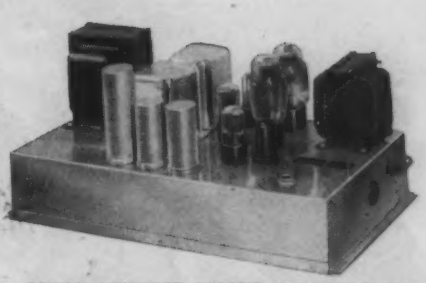
12 ADDITIONAL FEATURES

a. Auxiliary AC outlet internally controlled by on-off switch.
b. Socket for 6.3 volt pilot light.
c. Recorder output terminal.
d. Microphone shorting type terminal.
e. Separately fused for protection.
f. Tapped AC line transformer. Low line tap for voltages of 103 volts to 117 volts and a high line tap for line voltages of 118 to 132 volts. This will give maximum performance of the amplifier regardless of the line voltage by the adjustment of the line tap.

This equipment is designed to conform to the regulations of the Board of Fire Underwriters.



PRE-AMPLIFIER CHASSIS — 15¼" x 7¼" x 2½" — aluminum, finished in an alumilite finish.



POWER AMPLIFIER CHASSIS — 16" x 10½" x 2" — base is steel, chromium plated and polished.

Make your own record player or sound system deliver fidelity, volume, beauty "out of this world" with a

SCOTT Amplifier

Here is the amplifier you have always wanted for your own record player, loud-speaker installation, or sound system.

Now you can have a Scott—an amplifier used in one of the finest Scott instruments—designed to deliver fidelity, tonal quality, volume, range, and beauty of performance never before available.

Features of Two Units

The amplifier comprises two units—a pre-amplifier chassis (including the famous Scott Music Control with Dynamic Noise Suppressor*), and a power amplifier chassis. Fourteen tubes, including two rectifiers —two preliminary stages of audio amplification—a driver audio amplifier—a push-pull power output stage—suitable controls for volume regulation and continuous adjustment of bass and treble response are among the features.

This fine instrument, because of its power handling capacity and wide audio range, delivers reproduction of voice and music with fidelity and range which satisfy the most critical listener. The power output allows reproduction of musical selections regardless of dynamic range, because even on the peaks of volume the capacity of the amplifier is seldom used. The instrument will transmit the entire range of frequencies between 20 and 20,000 cycles without distortion.

No Blast or Distortion

This extremely wide range, beyond that of the average human ear, means that the sheer beauty of the music is undisturbed, without blast, distortion, or a tendency to "spill over" even on fortissimo passages.

The famous Scott Music Control, with the Dynamic Noise and Scratch Suppressor*, brings out soft musical passages in all their delicate beauty, free from annoying scratch and rumble. In loud, brilliant passages, the circuits permit full passage of all the tonal range built into the record. This control, used with the Scott infinite bass and treble controls and volume control, gives you command of performance second only to that of the conductor who presented the music when recorded.

Limited quantity available. Order now for immediate delivery.

SPEAKERS—*For balanced performance with Scott Amplifiers. Prices on request.*

RECORD CHANGERS—*Special prices for Garrard Record Changers.*

* *Hermon Hosmer Scott Patents Pending.*

Send us this coupon with your certified check or money order and we will ship this amplifier express prepaid to any place within the continental United States at a price of $180.00. Test it for five days and if you are not entirely satisfied, return it to us express collect and we will cheerfully refund your money, providing the instrument reaches us in the same condition in which it was sent.

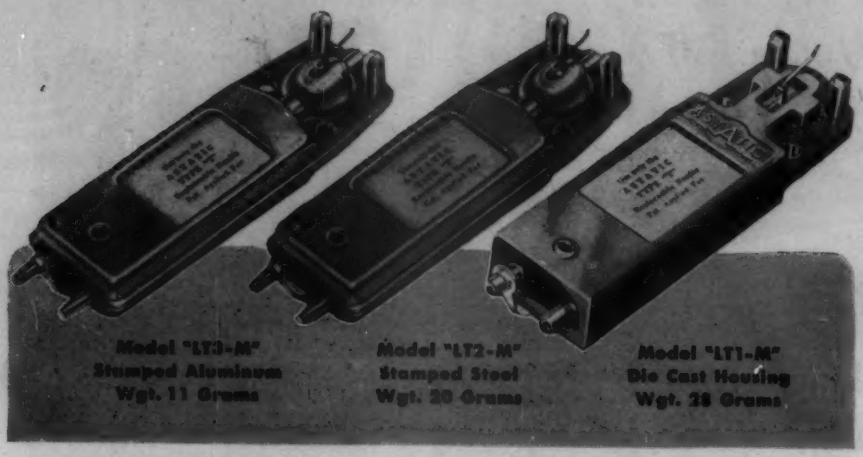
Scott Radio Laboratories, Inc.
4541 Ravenswood Avenue, Chicago 40

FIVE DAYS' TRIAL
MONEY-BACK GUARANTEE

NAME_____

ADDRESS_____

CITY-ZONE_____ STATE_____



There's an Astatic Model "LT" CARTRIDGE For Every Pickup Arm

IN ORDER that radio-phonograph engineers may select a cartridge of the proper weight to provide optimum needle pressure and pickup inertia characteristics with various types of arms, Astatic's new low pressure, low needle talk "LT" Series Cartridges are now supplied in three different type housings. For improved clarity and quiet of phonograph reproduction, Astatic "LT" Cartridges are highly recommended for new installations in all types of automatic record changers and manually operated phonographs. The response of these cartridges is exceptionally smooth over the entire frequency range from 50 to 10,000 c.p.s., with a gradual roll-off commencing at approximately 4,000 c.p.s. Minimum Needle Pressure, ¾ oz. Output Voltage, 1.0 Volt average at 1,000 c.p.s.

TYPE "T" Replaceable NEEDLE

This stainless steel type "T" Needle with electro-formed precious metal tip is used with all "LT" Cartridges.

Needle quickly and easily released for replacement by loosening set screw in head of Cartridge.

BOOTH 125 at the PARTS SHOW
Chicago · May 11-14

Also highly recommended is Astatic's de luxe "QT" Series (Quiet Talk) Cartridge, employing a matched, replaceable Type "Q" Needle with sapphire or precious metal tip.

Literature is Available

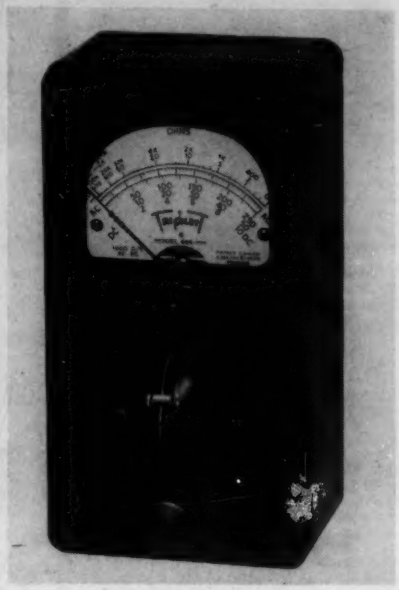
THE Astatic CORPORATION
ASTATIC CONNEAUT, OHIO
IN CANADA: CANADIAN ASTATIC LTD. TORONTO, ONTARIO

Astatic Crystal Devices Manufactured under Brush Development Co. patents

plished in a new detection system with circuits designed to resolve simultaneous or random counts in ten channels. Correct count is attained even though parts fall past the ten photoelectric detectors at the same instant.

Pocket Multimeter

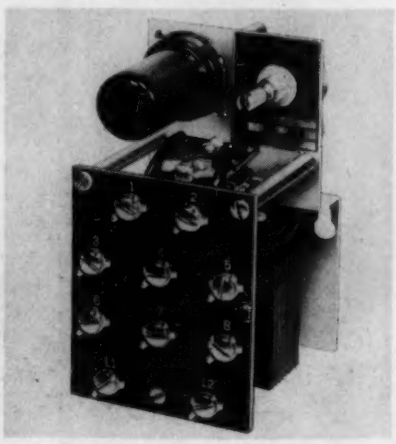
TRIPLETT ELECTRICAL INSTRUMENT Co., Bluffton, Ohio. Model 666-HH volt-ohm-milliammeter is a pocket-



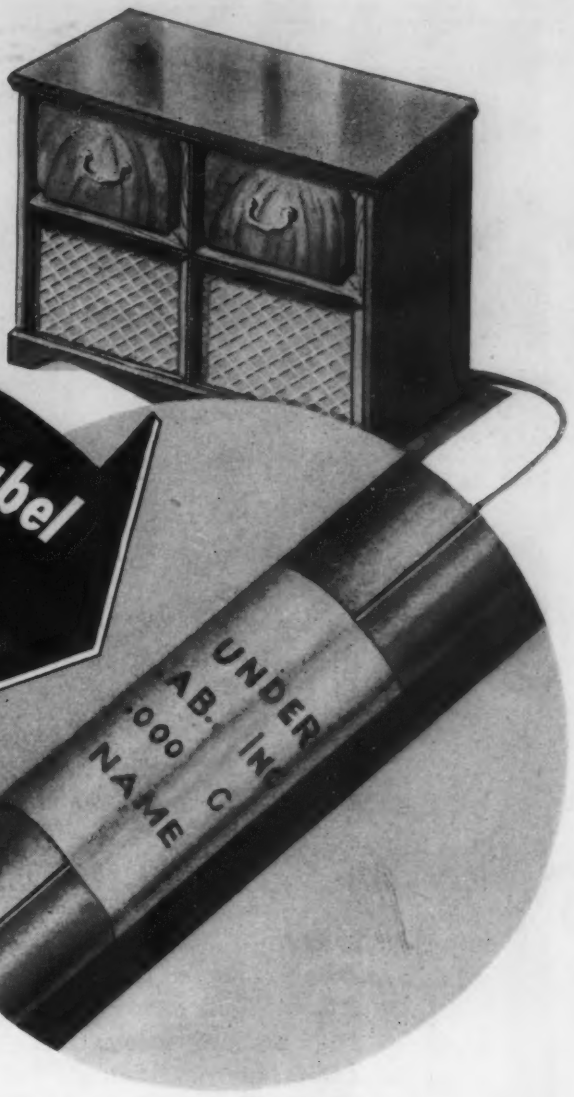
size unit designed to fill the usual measurement needs of industrial engineers, laboratory technicians, and the like.

Relay Control

R-S PRODUCTS CORP., Philadelphia, Pa., announces the new Leveltronic relay with double-pole, double-throw action for pressure, liquid



Electronic Equipment Manufacturers—



A Newly Perfected Cord Label
RECOGNIZED BY
Underwriters' Laboratories

To Match the Perfection Of Your New Products!

Specify

PRESSURE SENSITIVE
Underwriters' Approval Labels

On All Cord Sets or Power Supply Cords You Order!

Protect product quality! Give consumers the approved cord label they prefer! The PRESSURE SENSITIVE UNDERWRITERS' APPROVAL LABEL won't fall or wear off the cord, won't nick hands, clothing or drapes, will keep its handsome appearance for the cord's life!

REMEMBER, PRESSURE SENSITIVE UNDERWRITERS' APPROVAL LABEL IS THE LABEL RADIO BUYERS WILL LOOK FOR.

Ask for names of manufacturers supplying pressure sensitive underwriters' approval labels or fill in and send coupon below to your present cord supplier.

Gentlemen:

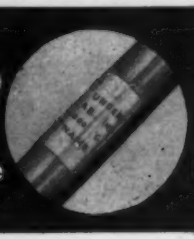
We'd like to see a Pressure Sensitive Underwriters' Approval label on a sample of the cord set you regularly supply. Please rush sample.

Firm Name .....

Address .....

Your Name ..... Position .....

Pressure Sensitive Labels



P. O. Box 305, Providence Rhode Island

There is big news in these small packages

Subminiature vacuum tubes which provide an expanding horizon for the development of many new and unique electronic circuit requirements.

VX-41A ELECTROMETER TETRODE | VX-32B TRIODE | VX-21 DIODE

Actual sizes

VX-41A ELECTROMETER-TETRODE
10 ma. filament current at 1.25 volts
1.5 to 1.1 filament voltage
10^{-15} amperes grid current
2,000 hours minimum life test
13 amplification factor

VX-32B TRIODE
10 ma. filament current at 1.25 volts
1.5 to 1.1 filament voltage
10^{-13} amperes grid current
25,000 ohms plate resistance
65 micro mhos transconductance

VX-21 DIODE
10 ma. filament current at 1.25 volts
1.5 to 1.1 filament voltage
3,000 volts inverse peak
10^{14} ohms insulation resistance
600 microampere emission

Data sheets on subminiature tubes, hi-megohm resistors, and our complete line of radiation measuring instruments available on request.

Department A

THE VICTOREEN INSTRUMENT CO.
5806 HOUGH AVE., CLEVELAND 3, OHIO

and temperature controls. In operation of the unit, the circuit uses a positive-acting thyratron with the tube current limited to less than ½ its maximum value. Two models cover a range of 20 ohms to above 2 megohms with continuously variable sensitivity giving 2 to 1 discrimination over the full range.

Sealed Midget Relay

PRICE ELECTRIC CORP., Frederick, Md. Made with coil resistances up to 9,500 ohms and contact combina-

tions including 4pdt a new Husky type sealed midget relay is available with mounting feet at the armature end. Palladium silver, and tungsten contacts are supplied to fit load requirements.

13-Channel Marker

KAY ELECTRIC CO., 23 Maple Ave., Pine Brook, N. J. Mega-Marker Sr. provides accurate sound carrier frequencies for all thirteen television channels crystal controlled

to an accuracy of 0.01 percent. Single-dial control avoids necessity for calibration charts. Price is $195 fob.

Small Motor

T. C. SMITH MFG. CO., Springfield, Ill., has a new fractional horsepower

THIN METHACRYLATE SHEET IS HERE

NO, NO ILLUSTRATION
We're leaving it up to you to fill this space with mental pictures of ways you can use this new Plax product.

Add another first to Plax's long list of innovations. This time it is methacrylate sheet that is really *thin*. It is available now and you can order for immediate delivery. Thicknesses range from .010" through .045."

You know methacrylate — its crystal clarity, brilliance of finish, dimensional stability and durability. Well, here are these advantages under your hand for the first time in *thin* sheet form. You can have it run-of-mill or press polished.

You probably have had all sorts of ideas for a material like this. It lends itself admirably to numberless applications like boxes, radio dial coverings, spacers, watch crystals, other drawn parts, light louvres, etc.

CHART ON "HOW TO USE PLASTICS"

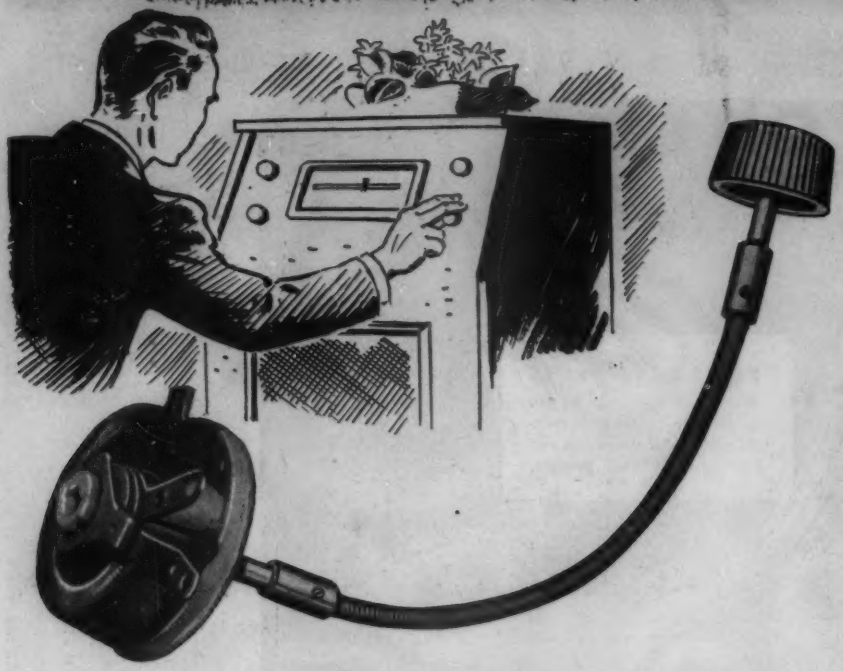
Now available for the asking is a table of properties for six materials available from Plax in various forms and formulae. This has been incorporated in the Plax catalog, which also contains helpful information on the primary uses of each material.

A copy will be sent promptly upon receipt of your request.

Between the resources of Shaw Insulator Company, Irvington 11, N. J., and Plax Corporation, Hartford 1, Conn., you can find help on virtually every material and method in plastics today.

P. O. BOX 1019 ★ HARTFORD 1, CONNECTICUT
In Canada — Canadian Industries, Ltd., Montreal

Simplify WITH S.S.WHITE FLEXIBLE SHAFTS



HOW TO MEET 6 "MUSTS" IN EQUIPMENT DESIGN

Certain electrical and physical requirements must be met in creating radio and electronic equipment that will be satisfactory from the standpoint of both production and use. The 6 principal "musts" are these

1 Optimum circuit efficiency
2 Easy assembly and wiring
3 Space saving
4 Convenient operation
5 Accessibility for servicing
6 Orderly panel arrangement

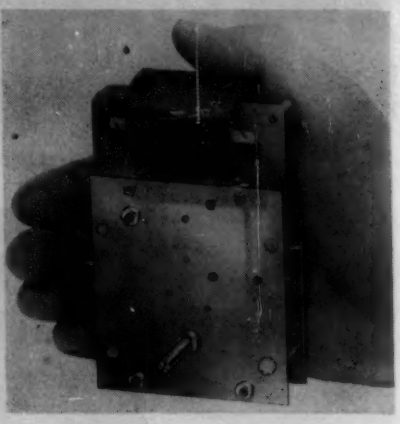
With respect to variable elements, you can satisfy all six by coupling such elements to their control knobs with S.S.White remote control flexible shafts, because this *allows you to locate both elements and controls in their most advantageous positions.* And you sacrifice nothing in the quality of control, because, with proper application, S.S.White remote control shaft operation is every bit as smooth, easy and sensitive as a direct connection.

THIS 260-PAGE FLEXIBLE SHAFT HANDBOOK WILL GIVE YOU FULL DETAILS—

A free copy will be mailed, if you write for it on your business letterhead and mention your position.

S.S.WHITE INDUSTRIAL DIVISION
THE S. S. WHITE DENTAL MFG. CO.
DEPT. E 10 EAST 40th ST., NEW YORK 16, N. Y.
FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED INSULATORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

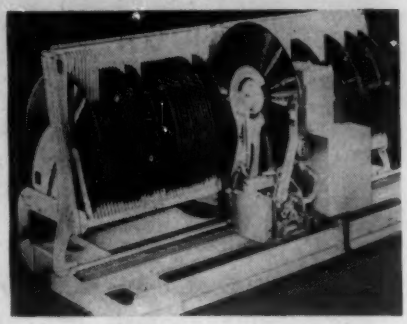
One of America's AAAA Industrial Enterprises



motor of the shaded-pole, induction type. With 20 watts input at 115 volts, 60 cycles, the no-load speed is 20 rpm on the output shaft. Performance curves and other information will be supplied on request.

Superchanger

J. P. SEEBURG CORP., 1500 N. Dayton St., Chicago 22, Ill. A library of 100 records to give 200 selections



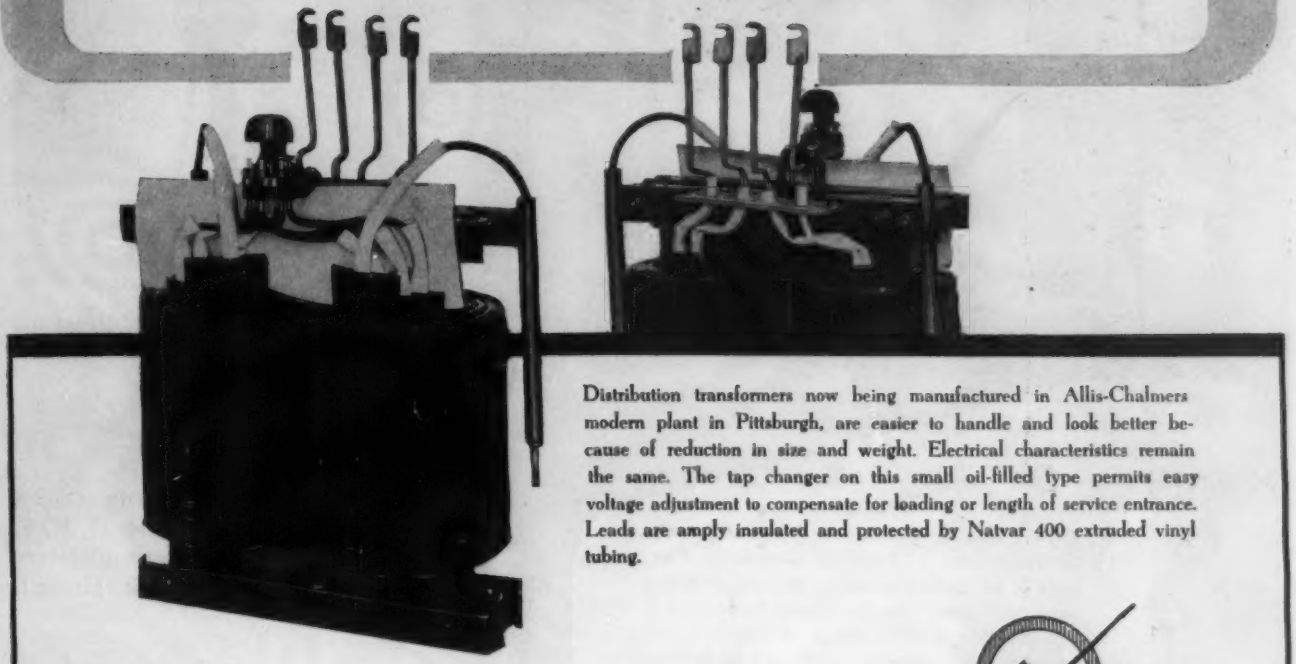
can be played continuously with the new mechanical brain shown. The unit moves back and forth along a track to select the desired record, plays it vertically, and then returns it to the rack. The pickup arm has a double stylus.

High Temperature Tubulars

SOLAR MFG. CORP., 1445 Hudson Blvd., North Bergen, N. J. Types ST and STM tubular capacitors are plastic encased and heat resistant

ALLIS-CHALMERS INSULATES AND PROTECTS TRANSFORMER LEADS

WITH **NATVAR 400**



Distribution transformers now being manufactured in Allis-Chalmers modern plant in Pittsburgh, are easier to handle and look better because of reduction in size and weight. Electrical characteristics remain the same. The tap changer on this small oil-filled type permits easy voltage adjustment to compensate for loading or length of service entrance. Leads are amply insulated and protected by Natvar 400 extruded vinyl tubing.

With capacity at an all-time high, utilities are doing an outstanding job of keeping up with the relentlessly increasing demand.

Allis-Chalmers distribution transformers, in serving widening areas and areas of increasing density, have handled loads far in excess of their rated capacity for considerable lengths of time without interruption.

Natvar 400, approved for continuous operating temperatures of 105°C., gives lasting insulation and protection to the leads because of its uniformly superior resistance both to high temperatures and to oil.

Prompt deliveries — either from the stock of a wholesaler near you — or direct from our own. Full Underwriters' report on request.

Natvar

Natvar Products

- Varnished cambric—straight cut and bias
- Varnished cable tape
- Varnished canvas
- Varnished duck
- Varnished silk
- Varnished special rayon
- Varnished Fiberglas cloth
- Silicone coated Fiberglas
- Varnished papers
- Varnished tubings and sleevings
- Varnished identification markers
- Lacquered tubings and sleevings
- Extruded vinyl tubing
- Extruded vinyl identification markers

Ask for Catalog No. 21

THE NATIONAL VARNISHED PRODUCTS Corporation

TELEPHONE
RAHWAY 7-2171

CABLE ADDRESS
NATVAR: RAHWAY, N. J.

201 RANDOLPH AVENUE ★ WOODBRIDGE NEW JERSEY

1001 USES IN THE ELECTRONICS INDUSTRY

COAXITUBE

Here's a new "performance-proved" metal shielded wire . . . Precision Coaxitube. Consists of an inner conductor, insulation and a seamless metal tubular shield. Coaxitube is available in a wide range of characteristic impedances, capacity and power ratings with single or multiple inner conductors. You have your choice of any seamless nonferrous metal shield.

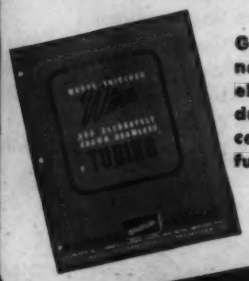
SEAMLESS SHIELD reduces leakage and transmission loss, eliminates interference.

PROTECTION AGAINST CORROSION, abrasion, acids and dirt afforded by solid shield.

TAKES ANY SHAPE and still remains coaxial, due to unique construction.

FORMED COMPONENTS such as closely coupled coils of inner and outer conductors, shielded grid and plate leads, available on good delivery.

APPLICATION ENGINEERED to suit your performance requirements.



Get all of the facts on this new development for the electronics and instrument industries. Write for your free copy of the booklet giving full details on COAXITUBE.

PRECISION TUBE CO.

Factory: 3824-26-28 TERRACE ST., PHILADELPHIA, PA.

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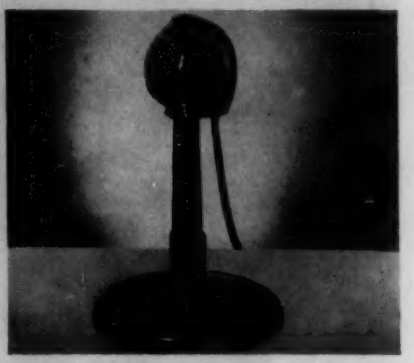
up to 100 degrees C. They are also impervious to moisture. Write for descriptive bulletin.

Crystal Mike

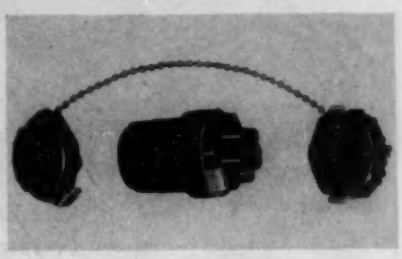
TURNER Co., Cedar Rapids, Iowa. Model 35X Fireball microphone is recommended for home recording,



paging systems, public address, and amateur communications. The base is detachable.

H-V Connector

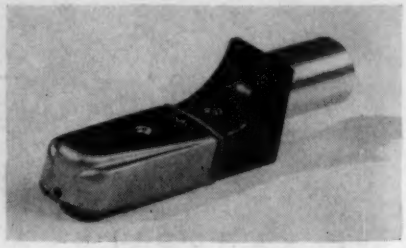
WINCHESTER ELECTRONICS Co., 6 East 46th St., New York 17, N. Y. A 6-contact, high-voltage miniature connector for photoflash, aircraft,



and other equipment has precision machined and silver plated contacts. Polarization is positive and a spring lock prevents accidental disconnection. A weatherproof cover is provided.

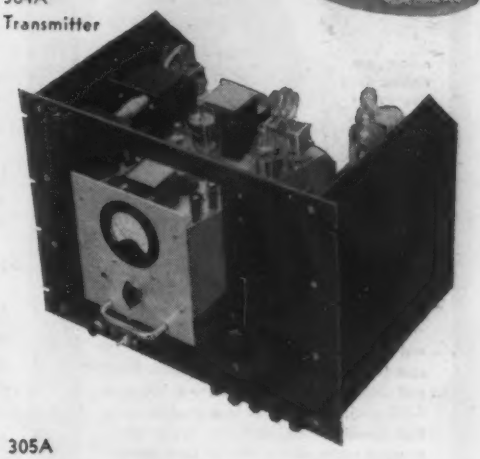
Reproducer

AUDAK Co., 500 Fifth Ave., New York 18, N. Y. Audax model 79-G



WILCOX .... *First Choice* OF THE TRANS WORLD AIRLINE

364A
Transmitter



TWA EQUIPS GROUND STATIONS WITH NEW WILCOX VHF RECEIVERS AND TRANSMITTERS

New Fixed Frequency Equipment Offers New Performance Features in the 118-136 Mc. Band

- Selectivity Permits 100 Kc. Adjacent Channel Operation
- Co-Axial Transmission Line Relay Allows Common Antenna
- .005% Frequency Stability Without Temperature Control
- New Noise Limiter Means Better Reception
- Design Simplicity Simplifies Service

305A
Receiver

Write Today For Complete Information on the WILCOX 305A Receiver and 364A Transmitter

WILCOX MEANS ***Dependable Communication***

WILCOX ELECTRIC COMPANY • Kansas City 1, Missouri

TWO

TWO OUTSTANDING DEVELOPMENTS IN THE DESIGN OF FRACT. H.P. INSTRUMENT-TYPE MOTORS

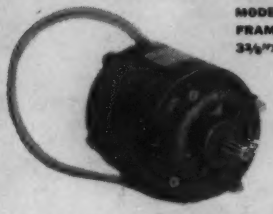
1

DUAL-SPEED

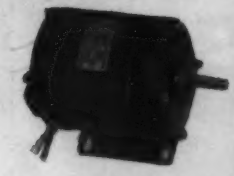
HYSTERESIS TYPE

SYNCHRONOUS MOTOR

MODEL ALH
FRAME SIZE
3⅛"x4-5/16"



MODEL GH
FRAME SIZE
4⅜"x5⅞"



Rated for 115 v. and 220 v., a.c., from 1/50 to 1/150 H.P., depending on speed and frame size; base or face mounted.

REVERSIBLE WHILE RUNNING!

CHANGES SPEED WHILE RUNNING!

Simple SPDT switch instantly reverses motor while running, at either speed. Speed control by DPDT switch . . . for 900 and 1800 rpm (also will be for 600 and 1200, 1800 and 3600, and combinations as 900 and 3600 rpm). Combine for low speed forward, high speed reverse, and vice versa. Absolutely constant torque thruout rotor revolution, eliminating "wows". 1-phase and 2-phase in either frame, and also 3-phase in 'G' frame. Single-speed units available at higher H.P. ratings.

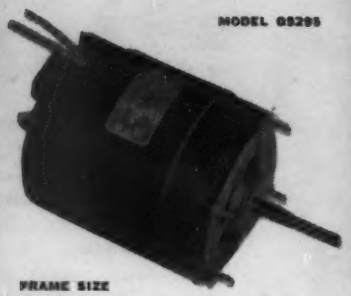
2

DUAL-VALUE

CAPACITOR TYPE

SYNCHRONOUS MOTOR

MODEL GS295



FRAME SIZE
4⅜"x5⅞"

In our opinion Model GS295 delivers more power for its size and weight than any other motor of this type.

EFFICIENCY 53% AT FULL LOAD

Rated at 1/12 HP at 1800 rpm, 110 v. and 220 v., a.c., with high starting torque exceeding full load. Shows only 40° temperature rise up to full load and is, therefore, rated for continuous service. INSTANTLY REVERSIBLE WHILE RUNNING; extremely quiet in operation and highly economical in use.

ENGINEERED BY ELINCO . . . DESIGNERS AND MANUFACTURERS OF PRECISION FRACTIONAL H.P. MOTORS AND GENERATORS OF INSTRUMENT TYPE TO MEET SPECIAL REQUIREMENTS.

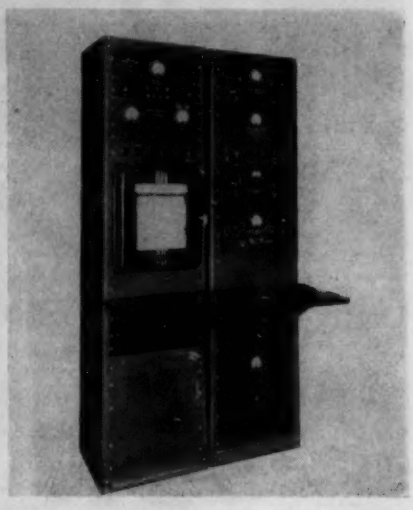
ELECTRIC INDICATOR CO.

PARKER AVENUE STAMFORD, CONN.

is one of nine tuned-ribbon units available for Garrard changers. The unit is linear from 50 to 10,000 cycles. Point pressure is about 24 grams. Output is about minus 30 db.

Mass Spectrometer

GENERAL ELECTRIC CO., Schenectady 5, N. Y. A new recording mass spectrometer is used to determine



the composition of material. It can measure over the mass range from 1 to 350 and is adjustable to begin recording at any required mass. The instrument is built in two parts, a control unit and tube rack. Additional information is given in GEA-4907.

Miniature Battery

OLIN INDUSTRIES, INC., New Haven, Conn. The plastic cells illustrated interlock with each other to form a battery that requires few of the

Watch Master

Frequency Standards

GUARANTEED ACCURACY
1 part in 100,000
. (.001%)

Type 2121 A.

TERMINATION
Front and Rear
CONSTRUCTION
Standard 8¾" x 19" Panel
HOUSING
8¾" x 19" x 8" Metal Cabinet
WEIGHT
25 pounds

Uses

Time bases, rate indicators, clock systems, chronographs, geo-physical prospecting, control devices and for running small synchronous motors.

Features

1. **Bimetallic, temperature-compensated fork, no heating or heat-up time is required.**
2. **Fork is hermetically sealed, no barometric effects on frequency.**
3. **Precision type, non-ageing, low coefficient resistors used where advantageous.**
4. **Non-linear negative feedback for constant amplitude control.**
5. **No multi-vibrators used.**
6. **Synchronous clock simplifies checking with time signal.**

Specifications

Accuracy—1 part in 100,000 (.001%).
Temperature coefficient—1 part in 1,000,000 per degree centigrade (or better).
Outputs—

1. **60 cycles, sine wave, 0-110 volts at 0 to 10 watts (adjustable).**
2. **120 cycle pulses, 30 volts negative.**
3. **240 cycle pulses, 30 volts positive and negative. Pulse duration, 100 micro-seconds.**

product of

AMERICAN TIME PRODUCTS INC.

580 Fifth Avenue **New York 19, N. Y.**

Operating under patents of the Western Electric Company

American Time Products, Inc.,
580 Fifth Ave., New York 19, N. Y.
Gentlemen:
Please send descriptive folder, No. 2121A.

Name.....

Company.....

Address.....

City..... State.....

Now... at a sensationally
LOW PRICE!
ECA QUALITY
FM & TELEVISION
Sweep Signal
GENERATOR
$34.95 COMPLETE

A MUST FOR FM & TELEVISION SERVICE SHOPS!

ECA

Here's great news for FM and TV Service Shops! A new, top quality sweep signal generator—product of a manufacturer with vast resources, advanced engineering "know-how", and wartime experience in producing test equipment. DIRECT FROM THE FACTORY—at a phenomenally low price!

FRONT PANEL CONTROLS
- Sweep width 500 KC to approx. 10 MC
- Phasing control
- Tuning vernier control 10 to 1 ratio
- Selecto switch FM—RF—CAL
- RF Output control
- 60 cycle horizontal sweep output
- Amphenol RF output shielded connector

FREQUENCY RANGE 3 BANDS
(No band switching necessary)
(2 to 227 Megacycles)
- 2—77 MC
- 40—154 MC
- 151—227 MC
- Calibration and reference scales
- Dial scale length

TUBE LINEUP
- 6C4—Fixed frequency modulated oscillator
- 6C4—Continuously variable beat frequency oscillator
- 6C4—Mixer—Cathode follower output tube
- 5Y3—Rectifier tube

GENERAL INFORMATION
- High frequency insulation throughout
- Maximum output 500,000 U/V
- Power required 105-125 Volt 50-60 AC 35 Watts
- Power line filter built in
- Special Midline capacity tuning condenser
- Pilot light line indicator
- Generator output can be used either frequency modulated or pure RF

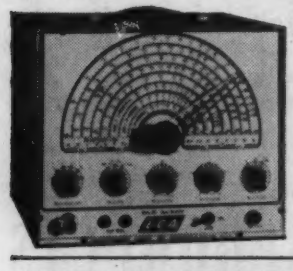
RADIATION LOOP AND ALIGNMENT WAND

Provides loose coupling. Checks loop-oscillator tracking. Increases efficiency of receiver's alignment or mistracking. Enables the service engineer to make gain measurements. Professional appearance and results. May be used on any signal generator. Complete with operating instructions. **$5.95**

FM FRONTEND
Complete with 3 tubes, including Magic Eye. 88-108 MC.

For use with 10.7 MC I.F.S., high Q resonant tuned lines. Heavy silver overlay on lines and contacters. High frequency insulation throughout I-RF stage, detector, and oscillator. Large 7" slide rule dial. Chassis floated, non-microphonic.

$15.95



AM SIGNAL GENERATOR

8 RF bands. Frequency coverage 100KC-75 MC. External modulation from 40 to 30,000 cycles. Internal modulation at 440 cycles. Phase shift audio oscillator and internal modulator. A.C. 105 to 120 volts, 50 to 60 cycles. Special Hammarlund variable condenser; 3-step RF attenuator Continuously variable RF-AF attenuator control. Ultra stable two terminal RF oscillator. Pilot light line indicator. Cathode follower output tube. Modulator percentage continuously variable from front panel, internal or external, 0 to 100%. Heavy 16-gauge steel cabinet. Complete with 4 (standard brand) tubes. Amphenol co-axial connecting cable, ground cable, operating instructions and guarantee. **$32.50**

BACKED BY ECA WITH R.M.A. GUARANTEE. FOR PROMPT DELIVERY, RUSH YOUR ORDER TO-DAY TO DEPT. E-5. 20% DEPOSIT WITH ORDER REQUIRED. F.O.B. NEW YORK CITY

ELECTRONIC CORPORATION OF AMERICA
353 WEST 48th STREET • NEW YORK 19, N. Y. • PHONE: CIRCLE 6-1985

Write for ECA circular on parts and additional equipment.

soldered connections made in a more conventional type. It is expected that the improved construction will result in 20 percent longer life. A new 67½-volt B battery is made of three 15-cell stacks.

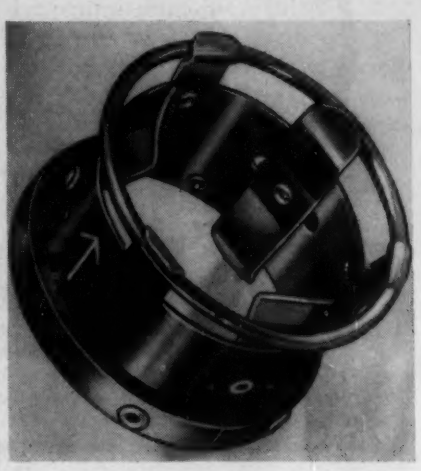
Television Capacitors

CORNELL-DUBILIER ELECTRIC CORP., South Plainfield, N. J. A new line

of television capacitors, DSTH, operate in the voltage range 3,000 to 6,000. They are oil-impregnated and wax-filled. A strap bracket can be furnished.

Ion Bender

CLAROSTAT MFG. CO., INC., 130 Clinton St., Brooklyn, N. Y. The Beam Bender consists of two ring



magnets held in a nonmagnetic mounting collar. Three spring fingers provide an adjustable fit on the neck of 7 or 10-inch television cathode-ray tubes employing electromagnetic deflection. The device acts as an ion trap.

Testing Meter

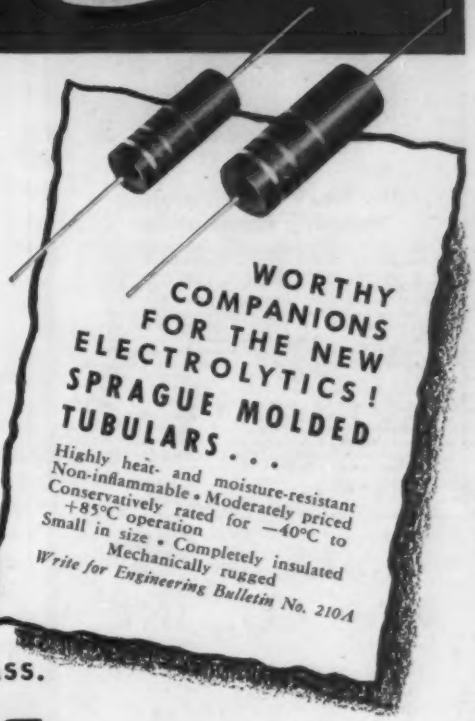
TRIPLETT ELECTRICAL INSTRUMENT CO., Bluffton, Ohio. Model 2405-A

Announcing A NEW LINE OF SPRAGUE ELECTROLYTIC CAPACITORS

For operation up to 450 volts at 85° C.

With some 7 times as many components in a television receiver as in the average radio, the possibility of service calls is greatly increased. The new SPRAGUE ELECTROLYTIC line offers the first practical solution to this problem.

Designed for dependable operation up to 450 volts at 85° C. these new units are ideally suited for television's severest electrolytic assignments. Every care has been taken to make these new capacitors the finest electrolytics available today. Stable operation is assured even after extended shelf life, because of a new processing technique developed by Sprague research and development engineers, and involving new and substantially increased manufacturing facilities. More than ever before your judgment is confirmed when you *SPECIFY SPRAGUE ELECTROLYTICS FOR TELEVISION AND ALL OTHER EXACTING ELECTROLYTIC APPLICATIONS!* Sprague Electric Company invites your inquiry concerning these new units.



WORTHY COMPANIONS FOR THE NEW ELECTROLYTICS!

SPRAGUE MOLDED TUBULARS . . .

Highly heat- and moisture-resistant
Non-inflammable • Moderately priced
Conservatively rated for —40°C to +85°C operation
Small in size • Completely insulated
Mechanically rugged

Write for Engineering Bulletin No. 210A

SPRAGUE ELECTRIC COMPANY · NORTH ADAMS, MASS.

SPRAGUE Capacitors * Koolohm Resistors

PIONEERS OF ELECTRIC AND ELECTRONIC PROGRESS

*Trademarks reg. U. S. Pat. Office

Designed for

M

Application

The No. 92101—Antenna Matching Preamplifier

The Millen 92101 is an electronic impedance matching device and a broad-band preamplifier combined into a single unit, designed primarily for operation on 6 and 10 meters. Coils for the 15 and 20 meter bands as well as television channel 2 thru 6 inclusive also available. This unit is the result of combined engineering efforts on the part of General Electric Company and the James Millen Manufacturing Company. The No. 92101 is extremely compact, the case measuring only 6¼" x 5 3/16" x 3". The band changing inductor unit plugs into the opening in the front of the panel. Plug is provided for securing power requirements for the 6AK5 tube from the receiver. Coaxial connectors and plugs are furnished for the antenna and receiver connections.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY

MALDEN

MASSACHUSETTS

M

meter has 35 ranges including voltages to 1,000 volts. Direct current ranges are 0 to 50 microamperes up to 10 amperes; alternating current up to 10 amperes. Output and capacitor testing can also be performed. Resistance in the usual ranges can be measured accurately on the 6-inch meter.

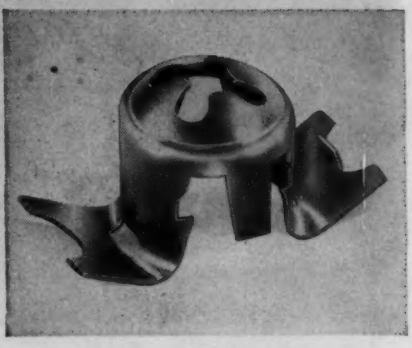
Industrial Speaker

RACON ELECTRIC CO., INC., 52 East 19th St., New York 3, N. Y. A new radial re-entrant horn speaker suitable for all types of industrial sound and public address installations can be mounted to cover all directions. It handles 25 watts continuous power and peaks of 35 watts. Frequency response is from 300 to 6,000 cycles.

Fuse Clips

AMERICAN MOLDED PRODUCTS CO., 1652 N. Honore St., Chicago 22, Ill. A new low-cost fuse clip tinned for

Big Savings with PALNUT Trademark **Coil Tube Fasteners**



DOES 3 JOBS!

1. Provides required tension on iron core adjusting screw to maintain accurate setting, thru use of specially designed "Palnut" thread form.

2. Provides support for the RF or IF coil tube. All coil tube length above chassis is usable electrically, as fastener does not extend above chassis.

3. Snap the assembly into chassis, shield can or terminal board. Provides absolute security and rapid assembly.

SAMPLES of this speedy, efficient "Palnut" Coil Tube Fastener, plus engineering data, sent upon request on your business stationery.

The PALNUT Co.

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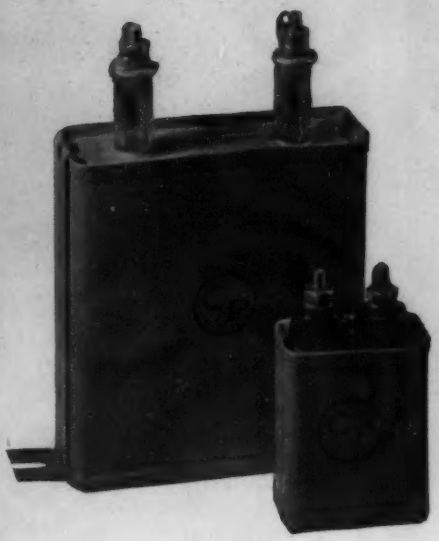


PLASTICON
Plastic Film Oil-Filled
CAPACITORS—

1. More Economical

2. Smaller—Lighter

3. Better Electrical Characteristics

1. MORE ECONOMICAL

MFD.	VOLTS DC	List Price PAPER CAPACITOR	List Price PLASTICON AOC	SAVING
10	1000	$15.18	$10.67	$4.51
4	2000	13.67	9.24	4.43
2	3000	22.78	15.40	7.38
1	4000	33.54	27.50	6.04
2	5000	48.73	41.25	7.48
Above are typical examples.				

PLASTICONS are the result of technological advances . . . cost less to manufacture, give better performance.

2. SMALLER—LIGHTER

MFD.	VOLTS DC	Approx. Weight		Approx. Cubic Dimensions	
		PAPER CAPACITORS	PLASTICONS	PAPER CAPACITORS	PLASTICONS
10	1000	1.95 lbs.	1.7 lbs.	31 cu. in.	30 cu. in.
4	2000	2.0	1.23	31	23
2	3000	2.0	1.21	31	19
1	4000	1.77	.94	28	19
2	5000	5.2	2.9	70	60

3. BETTER ELECTRICAL CHARACTERISTICS

	Paper Capacitors	Plasticons
Power Factor at 85°C 60 cycles	0.7%	0.3%
Resistance at 85°C megohms per Mfd.	40	100
Capacitance/Temp. Coefficient 100% at 25°	−40°C=73% +85°C=97%	−40°C=94% +85°C=103%

PLASTICON CAPACITORS given are Type AOC, mineral oil-filled.
PLASTICON ASC silicone-filled have better characteristics.
Paper Capacitors given are chlorinated diphenyl impregnated.

Condenser Products Company

1375 NORTH BRANCH STREET • CHICAGO 22, ILLINOIS

MANUFACTURERS of GLASSMIKE CAPACITORS and HIGH VOLTAGE POWER SUPPLIES.

TWO-CHASSIS CONSTRUCTION OFFERS HIGHEST QUALITY, MAXIMUM FLEXIBILITY

Record Scratch Banished!

The Fisher

DYNAMIC NOISE SUPPRESSOR WIDE RANGE AMPLIFIER

If you seek the finest in dynamic noise suppression, coupled with an amplifier that is precision built to exceptional, laboratory standards, there can only be one choice—THE FISHER Dynamic Noise Suppressor-Wide Range Amplifier,* custom constructed on two chassis. Here is its pedigree:

THE FISHER Wide Range Amplifier

1. A man's size amplifier with *only 1% distortion at twenty watts!*
2. Intermodulation distortion less than ½% at 5 watts output.
3. Uniform response from 20 to 20,000 cycles, plus or minus 1 db.
4. Hum level warranted less than 0.5 microwatts for one watt output.
5. Internal impedance less than 1.25 ohms.
6. 18 db of negative feedback.
7. Phono preamplifier *and first audio* operated entirely on DC to reduce hum.
8. Phono preamplifier comprises two triode stages operated in cascade, to minimize tube noise.
9. Phono circuit compensated for G. E. and Pickering pickups.
10. Exclusive, two-position pickup compensation for pre-emphasized recordings as well as recordings without rising characteristic at high end.
11. Two, medium gain auxiliary inputs for radio, etc., with selector switch *on front panel*, for convenience of use.
12. Output impedances 8 and 16 ohms. Professional quality line matching transformer for 125 and 500 ohms available at additional cost. (NOTE: Our experience has shown that it is not practical to design a *high quality* output transformer including both voice coil and line matching windings.)
13. Push-pull parallel output tubes, for conservative operation and superior output transformer design.

THE FISHER Dynamic Noise Suppressor

1. Incorporates six tubes, for optimum flexibility and effectiveness.
2. Two high frequency gates, dynamically controlled.
3. One switch position (see below) provides fixed filter tuned to 18 Kc. (Readily tuned to 10 Kc. by simple screw adjustment.)
4. Independent control voltage amplifier for operation of gates.
5. Double diode tube to provide DC control voltage for gate circuits.
6. Two cathode ray indicators to show individually the dynamic operation of high and low frequency gate circuits.
7. Muting circuit and connecting plug for complete silencing of needle swish in run-off groove and "blop" when the pickup lands on the next record.

GENERAL FEATURES

1. TWO-chassis construction, for optimum electrical performance and ease of installation in limited space—without undesirable long leads. Chassis constructed of 16-gauge steel.
2. Power available for external microphone preamplifier, etc., 250 volts at 50 ma. DC and 6.3 volts at 3 amperes AC.
3. SEVEN CONTROLS. (a) Volume Control. (b) Three-position switch for phono and two auxiliary inputs. (c) Six-position, On-Off and Range Switch (20-20,000 cycles, 20-10,000 cycles, 70-4000 cycles*, 90-3200 cycles*, 120-2700 cycles*.) *Frequency response with gates in *fully closed* position. With gates *fully open*, response is that in position 2, except that in position 5 response is limited to 6000 cycles. (d) Treble Control, continuously variable with maximum boost 16 db at 10,000 cycles, maximum cut 20 db at 10,000 cycles. (e) Bass Control, continuously variable with maximum boost 16 db at 100 cycles, maximum cut 32 db at 20 cycles. (f) Gate Sensitivity Control *on front panel*. Varies dynamic range of suppression for positions 3 to 5 of Range Switch and permits *optimum adjustment* for various input levels and background noise characteristics, instantly and easily. (g) Phono Equalization Switch, two-position.
4. Tube Complement. *Suppressor-Voltage Amplifier Chassis*: 2-12AT7, 1-6C4, 3-6BA6, 1-6AL5, 1-6AQ6, 2-6E5. Panel: 10½" x 19", height 8⅝", width 13", depth 8". *Power Chassis*: 4-7C5, 1-7A4, 2-5Y3. Panel: 8¾" x 19", height 7¼", width 14½", depth 8½".
5. Auxiliary AC Outlets. Two available, for tuner, turntable, etc., controlled by master On-Off Switch.
6. Jewel pilot light on front panel.

Licensed under Hermon Hosmer Scott patents pending for use only in phonograph and phonograph distribution systems.

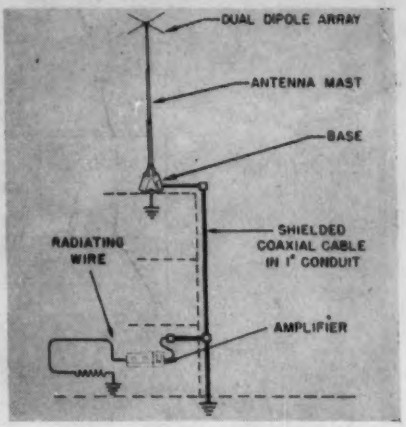
PRICE $254.50 • LIMITED QUANTITY AVAILABLE FOR IMMEDIATE DELIVERY

FISHER RADIO CORPORATION • 43 EAST 47TH ST., NEW YORK

soldering is available for type 3AG fuses. From one to four gangs are stocked; other sizes to order.

Static Remover

L. S. BRACH MFG. CORP., Newark 4, N. J., has developed the Puratone signal booster system shown



in the accompanying sketch. The system covers a frequency range of 0.3 to 20 mc for a-m, and 85 to 110 mc for f-m operation. It was designed to aid in demonstrating radio receivers in noisy city locations.

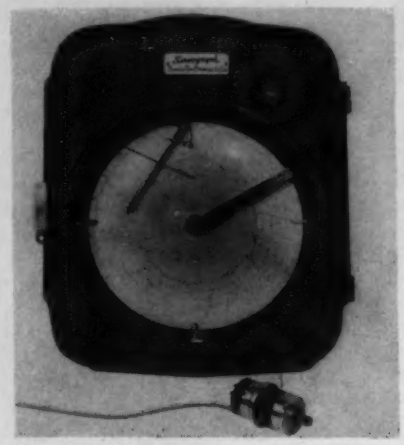
Contact Cleaner

WALTER L. SCHOTT CO., 9306 Santa Monica Blvd., Beverly Hills, Calif.

No-Ox contact cleaner is a neutral chemical cleaner and lubricant for bearings and shafts, volume and tone controls, band switches and tuning capacitors.

Position Recorder

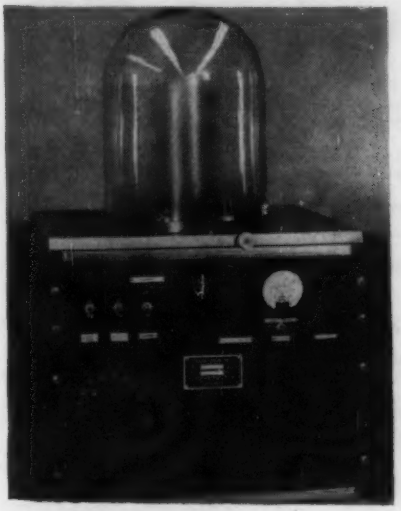
SERVO-TEK PRODUCTS CO., INC., 247 Crooks Ave., Clifton, N. J. Servograph position recorder utilizing a synchro transmitter and repeater has a variable ratio device that al-



lows compression or expansion of the transmitted signal to fill a 10-inch circular chart. The inking type recorder will record any variable that can be converted to angular rotation. A four-page brochure illustrates its use and gives specifications.

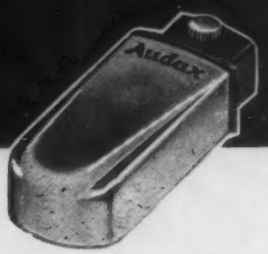
Vacuum Coater

DISTILLATION PRODUCTS, INC., 755 Ridge Road West, Rochester 13, N. Y. A table model vacuum unit



Audax

TUNED-RIBBON
reproducers



TUNED-RIBBON Pick-up model SA-79
(Actual Size—Special STUDIO-arm not shown)

• A model for every purpose

Jewel Stylus EASILY REPLACED BY USER

ADMIRABLY this revolutionary NEW line by Audax bears out the business maxim:—

"LOOK TO THE LEADER FOR LEADERSHIP"

* Because a "permanent-point"—be it diamond, sapphire or metal—will maintain its original shape for only a limited number of plays, after which it progressively erodes the record grooves, the importance of being able to replace it has always been of primary consideration. Heretofore such replaceability entailed severe penalties in range, compliance and point-pressure. Most of the TUNED-RIBBON models provide the all-important replaceability without those penalties.

SPECIFICATIONS TUNED-RIBBON SA-79

- Linear 50 cyc. to over 10 k.c.
- Point Pressure—about 24 grams
- Genuine Sapphire Stylus—EASILY REPLACED BY USER
- Output—about—30 db
- Impedance—200 ohms to 500 ohms
- Vibratory Momentum—very low
- Quick plug-in connectors
- Arm is aluminum, Special Studio Design, Tangent-Tracking, ball-thrust and pivot-point bearings in gimbal mounting—eliminating side thrust and drag.

TUNED-RIBBON delivers not only Wide Range, (which is but one link in the chain)—but also the vital factors so necessary for quality performance and EAR-acceptability . . . proving anew AUDAX right to the slogan:—

"The Standard by Which Others Are Judged and Valued"

Yes, Audax TUNED-RIBBON has put something into reproduced music that was not there before . . . let YOUR ears be the final judge.

* SEND FOR COMPLIMENTARY PAMPHLET ON THIS VITAL SUBJECT

AUDAK COMPANY

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CREATORS OF FINE ELECTRO-ACOUSTICAL APPARATUS SINCE 1915

"DIE-LESS" DUPLICATING

SAVES MAN HOURS AND DELAYS

DIE ACCURACY WITHOUT DIES

Send for CATALOG

BENDER

SHEAR

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DI-ACRO is Pronounced "DIE-ACK-RO"

"DIE-LESS" DUPLICATING

The DI-ACRO System of METAL DUPLICATING Without Dies

DI-ACRO PRECISION MACHINES DIE-LESS DUPLICATING

O'NEIL-IRWIN MFG. CO.

321 Eighth Avenue Lake City, Minnesota

NOW! SELF-CONTAINED, EXPERIMENTAL

SCHOOL & INDUSTRIAL LAB EQUIPMENT

Kepco Laboratory Multiple Power Supply Model 103, available separately

Kepco Electronic Instruction Panel Model 104, available separately.

Now you can perform electronic experiments simply, easily with the Kepco Electronic Instruction Panel. Here is a teaching aid that graphically illustrates vacuum tube principles — enables all students to grasp fundamentals in the laboratory.

Extremely versatile, the Kepco Electronic Instruction panel covers a wide range of tubes, comes with a packet of 23 keyed interchangeable circuit charts, 3 master charts and 12 blank keyed sheets for additional experiments. Panel contains 3 octal tube sockets, 18 binding posts. By placing a keyed circuit diagram on the panel and wiring the circuit, students determine tube and circuit characteristics.

For a basic electronic instructional aid that vastly simplifies the teacher's task, it's the Kepco Electronic Instruction Panel!

Now you can eliminate the use of cumbersome separate voltage supplies with the Kepco Laboratory Multiple Power Supply. Designed to be used with the Kepco Electronic Instruction Panel, this versatile, compact, easy-to-use unit supplies four commonly used voltages, is invaluable for the school or industrial laboratory.

CHECK THESE FEATURES:

Two continuously variable B supplies, adjustable from 0-300 volts at 120 m.a.
Variable (grid) supply, adjustable from minus 50 to plus 50 volts at 5 m.a.
6.3 volt filament supply at 5 amperes.
All connections made to sturdy, front panel binding posts.
Input: 105 to 125 volts, 50 to 60 cycles.
Two 5Y3 rectifiers, Two 6Y6 control tubes.
16" long, 8" high, 8¾" deep. Wgt.: 28 lbs.

WRITE FOR FULL INFORMATION TODAY!

Kepco LABORATORIES INC. Electronic Instruments

149-14 41st Avenue Flushing, New York

with Pyrex bell jar seven inches in diameter and ten inches high can attain a pressure of 0.1 micron. Complete apparatus for coating lenses and mirrors, preparing surface replicas for the electron microscope, and for demonstrations is available at $725.

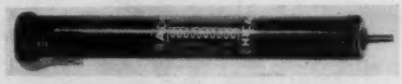
Portable Transcription Unit

BELL SOUND SYSTEMS, INC., 555 Marion Road, Columbus 7, Ohio. Model 2079 transcription phono and p-a system has a dual-speed turntable for both 16-inch transcrip-

tions and commercial recordings. It is supplied with an 8-inch p-m speaker that furnishes 5 watts audio power. Other features of the unit can be obtained upon request to H. H. Seay.

Pocket Signal Generator

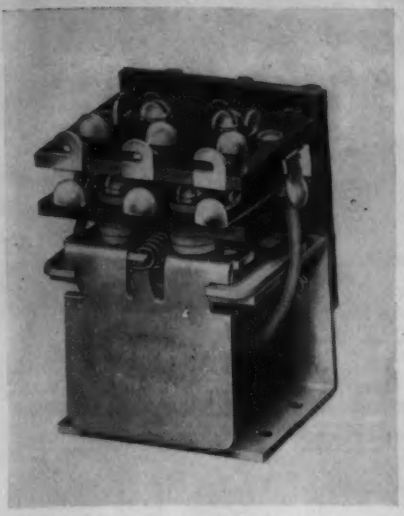
RADEX CORP., 2076 Elston Ave., Chicago, Ill. Pocketracer is an r-f and



audio signal source that operates from a single penlight cell. Oscillations radiated by the metal tip are picked up by antenna or other circuits and a modified signal-tracing technique is employed.

Redesigned Relay

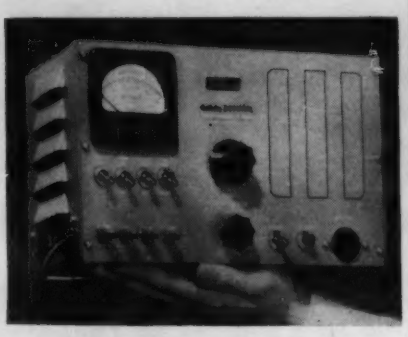
ALLIED CONTROL CO., INC., 2 East End Ave., New York 21, N. Y. Earlier relays types DO and DOY have been redesigned as illustrated to



make the types PO and POY. The latter type is intended for operation in the plate circuit of a vacuum tube and is a dual-coil device for d-c only. A catalog description is available.

Geiger Scaler

BERKELEY SCIENTIFIC CO., Sixth and Nevin Ave., Richmond, Calif. The decimal Geiger scaler model 1000 employs an electronic scale of 1,000 and a system of decimal in-



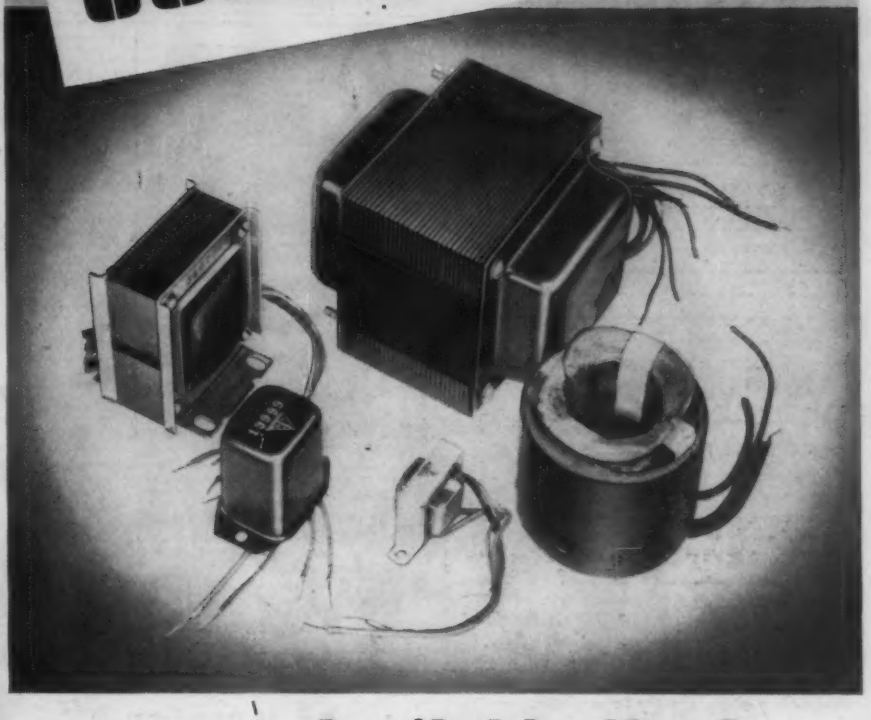
dication. Counts are shown by a single illuminated number on the front panel with a built-in mechanical register recording thousands. A self-contained high-voltage supply is adjustable from 100 to 2,500 volts. Other accessories for flexibility of operation are available and described in a bulletin.

Tiny Relay

ADVANCE ELECTRIC & RELAY CO., Los Angeles, Calif. A new miniature relay type 000 occupies 0.35 cubic inch and has spdt contracts rated at 0.35 amp at 60 volts d-c

*Here's your supply of N.Y.T

TELEVISION COMPONENTS



★ TELEVISION POWER TRANSFORMERS
★ DEFLECTION COILS
★ VERTICAL OUTPUT TRANSFORMERS
★ HORIZONTAL BLOCKING OSCILLATOR TRANSFORMERS
★ VERTICAL BLOCKING OSCILLATOR TRANSFORMERS

Available Now!

N.Y.T. facilities are now expanded to supply all types of inductive television components in quantity. Estimates will be supplied promptly on standard units or types wound to your exact specification. In addition to television components, N.Y.T. offers complete manufacturing service on power transformers, chokes, and audio transformers. Modern plant and winding equipment assures finest quality at low cost. Call or write today for information.

★ IN ANY QUANTITY!

NEW YORK TRANSFORMER CO.
ALPHA • NEW JERSEY

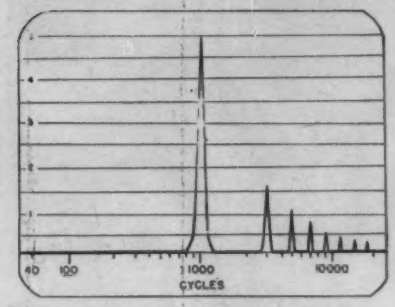
At last...

AN IMPROVED AND FASTER MEANS FOR AUDIO WAVEFORM ANALYSIS

PANORAMIC SONIC ANALYZER

Model AP-1

Now, in a matter of seconds, you can observe differences in waveform content produced by parameter variations. Model AP-1 indicates graphically the frequency distribution and amplitude of audio wave components. Slow, painstaking point-by-point frequency checks are eliminated. Ease of operation and simplicity of presentation make Model AP-1 ideally suited for production line as well as for laboratory usage.



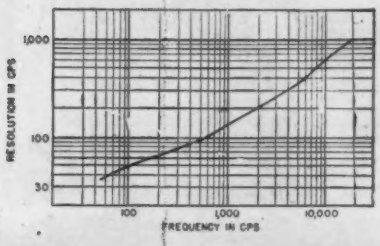
CHECK THESE FEATURES...

• Panoramic graphic presentation of frequency versus voltage amplitude • Continuous scanning from 40-20,000 c.p.s. in one second • Wide voltage range 0.05V to 500V • Simple operation • Direct simultaneous reading of voltage and frequency • Automatic variable selectivity for optimum resolution throughout frequency range (see graph below) • Both linear and log voltage calibrations • Built-in voltage calibrator • Frequency scale closely logarithmic

APPLICATIONS...

• Intermodulation measurements • Harmonic analysis • Noise investigations • Acoustic studies • Vibration analysis • Material testing

Write now for detailed specifications, price and delivery



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Exclusive Canadian Representative... Canadian Marconi Ltd.

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Leading manufacturers in the Radio and Electronics field regularly place their orders with us for:

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Let our modern plant help you in fabrication and assembly. Our Drafting and Model Depts. co-operate on engineering problems. Every facility for pilot and production quantities. Oxyacetylene and electric welding; aluminum spot welding; sand blasting.

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MODEL 2B 0.45
Actual size illustrated

RECHARGEABLE • NON-SPILL

VITAMITE

1 OZ. BATTERIES

(Smaller Than 2 Pen-Lights)

IDEAL FOR USE WITH

Miniature And Sub-Miniature Filament Type Tubes for HEARING AIDS, PORTABLE EQUIPMENT, ETC.

LARGER MODELS ALSO AVAILABLE
Write for Data and Literature

THE VITAMITE COMPANY

227 West 64th Street New York 23, N. Y.

"But you can't buy that kind of a motor..."

F—148

How many times have you heard somebody that ought to know better say something like that about motors, pumps, compressors or what-have-you? And how many times you heard somebody else say, "Oh yes you can! I saw just what we need in Blank Company's ad yesterday."

Advertising pages in this magazine are packed with *news* about your business. They contain information about products and services designed to help *you* do your job quicker, better and cheaper.

To be well-informed about the latest developments in *your* business, *your* industry . . . and to stay well-informed . . . *read all the ads too.*

HEADQUARTERS FOR INDUSTRIAL INFORMATION

McGRAW-HILL PUBLICATIONS

broadcast directional antenna arrays. Current ratios and phase angles in degrees are measured on a single meter. Bulletin 47 gives complete details.

Precision Drill

TELECTRONICS LABORATORY, Westbury, N. Y. The Microdrill is a precision instrument for rapid drilling of small holes. Vertical movement of the drill is accomplished by electronically controlling the amount of

electric power fed into a spring-loaded thermal unit. As power is increased, the unit elongates allowing a powerful spring to lower the spindle. Lamps indicate the position of the spindle. A collet for 0.004 to 0.025 inch pivot drills is provided on standard models.

D-C Timing Motor

A. W. HAYDON CO., Waterbury, Conn. Series 6300 motors operating on direct current are designed to integrate small instantaneous energy from a receiving type tube in order to perform greater amounts

it's KESTER for real soldering efficiency!

QUALITY — UNIFORMITY

Improve performance and decrease rejects by standardizing on Kester Rosin Core Solders. When manufacturing costs and maintenance operations are high, it will pay dividends to use the best cored solder made.

There is a Kester Rosin Core Solder that can be fitted to your needs. Troubled with a difficult soldering operation? Consult our engineers on any soldering problem. No obligation to you.

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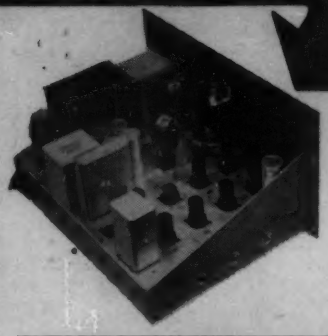
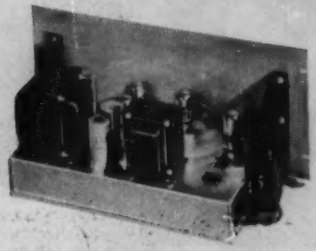
Factories also at
NEWARK, NEW JERSEY BRANTFORD, CANADA

HARVEY
for GOOD REPRODUCTION



GOODELL DYNAMIC NOISE SUPPRESSOR AMPLIFIER

18 watts with less than 2% harmonic distortion. Incorporates Scott noise suppression circuit; frequency range 20-20,000 cycles; 15 tubes; rack or cabinet mounting.....$248.00



FISHER DYNAMIC NOISE SUPPRESSOR WIDE RANGE AMPLIFIER

20 watts with only 1% distortion. Uses Scott noise suppression circuit; frequency range 20-20,000 cycles; 8 & 16 ohms output, line matching transformer extra $254.50

GRAY Transcription Arm—for your favorite cartridge; has adjustment and scale for ideal operating conditions	$35.00
Vibromaster Type K Arm—for GE and Pickering Cartridges; flat resonance characteristic	34.50
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GE Reluctance Cartridge—with sapphire needle	4.77
GE Reluctance Cartridge with diamond needle	29.70
GE Pre-amplifier to match GE Reluctance Cartridge to amplifiers not equipped with built-in pre-amplifier	5.95
Pickering Cartridge gives professional quality, with sapphire needle (S120M)	15.00
Pickering Cartridge with diamond needle (D120M)	39.75
Pickering Equalizer-Amplifier	19.50
Gray Equalizer Model 601,	42.50

All prices Net, F.O.B., N.Y.C.
Subject to Change Without Notice

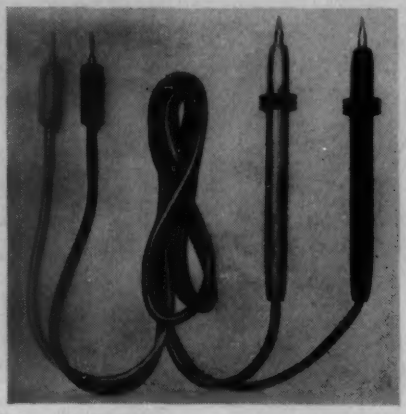
Telephone: LOngacre 3-1800

HARVEY RADIO COMPANY INC.
103 West 43rd St., New York 18, N. Y.

of work than relay devices. The high-impedance winding requires less than 270 milliwatts power input. A special rotor winding has approximately 7,000 ohms running impedance and draws 6 milliamperes at 45 volts d-c.

H-V Test Leads

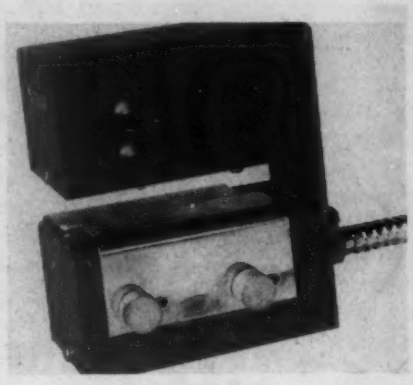
REINER ELECTRONICS Co., 152 West 25th St., New York 1, N. Y. Model 910 high-voltage heavy-duty test



leads are tested at 20,000 volts and are rated for 15,000-volt service. Tips are case hardened steel. Net price is $4.95.

Photo Edge Guide

LANGEVIN MFG. CORP., 37 West 65th St., New York 23, N. Y. Scanner type SC 311 is used to create a sig-



nal when the edge of a sheet moves from an established center line. It can be connected to a control relay or alarm. The photoelectric scanner will detect as little movement as 1/32 inch.

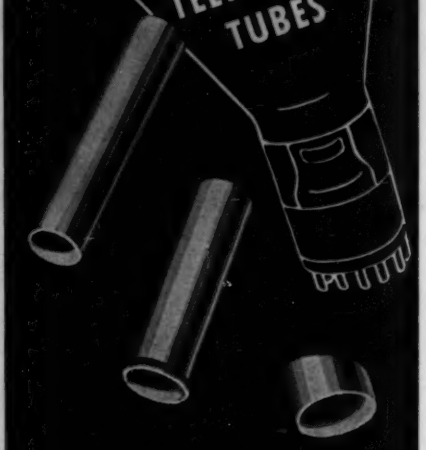
Cardioid Mike

TURNER Co., Cedar Rapids, Iowa. An improved cardioid microphone for commercial broadcast and

SUPERIOR ELECTRONIC PRODUCTS

used in the

GUN STRUCTURE OF TELEVISION TUBES



ANODE AND GRID CYLINDERS—

Straight cut, angle cut or rolled edge Tubing produced to very close tolerances.

DISC CATHODE ASSEMBLY—

Precision made and laboratory controlled to assure correct emission and cut-off characteristics.

Write for Print ED1-1.

The expanding television industry has turned to Superior's Electronic Division for the conception and production of these vital parts within the television tube.

THE BIGGER NAME IN SMALL TUBING *Superior* TUBE COMPANY
ELECTRONIC DIVISION
2500 GERMANTOWN AVENUE
NORRISTOWN, PENNA.

What?

A plastics advertisement with no parts illustrated?

No, we didn't forget to show a group of electrical parts molded to precision and within specified tolerances demanded by the manufacturer. Watertown has hundreds, yes, thousands of such parts which could be pictured here. But they wouldn't be the part you are now drawing blueprints for. That is the part we want to convince you we can make for you to meet your needs on the nose.

Why do we know we can do it? Because for thirty-five years Watertown has consistently been first in the development of new molding techniques, new equipment, laboratory testing and engineering. Over the years Watertown has saved hundreds of customers many thousands of dollars by their Watertown "know-how". We can do the same for you whether it requires injection, transfer or compression molding.

Write us concerning that plastic part you are contemplating and let Watertown engineers give you their ideas on how it can be done better. It will save you money.

•

A "PLUS" Watertown Service

Periodic testings of all molded parts from basic material to finished product are routine in Watertown's completely equipped laboratory. Accurate readings in flexural, tensile and compressive strengths, as well as stress and strain curves are obtained from a machine specifically designed for the fatigue testing of plastics. Fissures, porosity and stray metal inclusions are detected by a new electronic X-ray unit.

THE WATERTOWN MANUFACTURING CO.
777 ECHO LAKE RD., WATERTOWN, CONN.

Watertown
A NAME AS OLD AS THE PLASTICS INDUSTRY

AMPERITE MICROPHONES

The ultimate in microphone quality, the new Amperite Velocity has proven in actual practice to give the highest type of reproduction in Broadcasting, Recording, and Public Address.

The major disadvantage of pre-war velocities has been eliminated—namely "boominess" on close talking.

- ***Shout*** right into the new ***Amperite Velocity***—or ***stand 2 feet away***—the quality of reproduction is always excellent.
- ***Harmonic distortion is less than 1%*** (Note: best studio diaphragm mike is 500% higher).
- ***Practically no angle discrimination*** . . . 120° ***front and back.*** (Best studio diaphragm microphones—discrimination 800% higher).

AMPERITE
Velocity Microphones
for Public Address
Models RBHG, RBLG
List $42.00

P. G. Dynamic
Models PGH, PGL
List $32.00

- One Amperite Velocity Microphone will pick up an entire symphony orchestra.

STUDIO VELOCITY, finest in quality; ideal for broadcasting and Recording.
Models R80H, R80L. List $80.00
There is an Amperite Microphone for every requirement.

WRITE FOR ILLUSTRATED 4-PAGE FOLDER giving full information and prices.

"Kontak" Mikes
Model SKH, list $12.00
Model KKH, list $18.00

Address inquiry attention Dept. *E*

AMPERITE Company Inc.
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In Canada:
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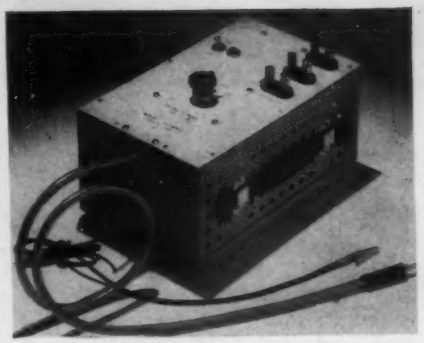
QUANTITATIVE MEASUREMENTS ON HIGH IMPEDANCE CIRCUITS

K



MODEL 102

PHANTOM REPEATER

AN INSTRUMENT AMPLIFIER WITH 200 MEGS.—6.0 MMF INPUT IMPEDANCE

The Phantom Repeater bridges voltmeters and cathode ray oscilloscopes, which have inputs of 1 megohm and 30 mmf, onto signal circuits of 50,000 ohms and higher—such as a pentode amplifier stage with its high resistance plate load—without the loss of voltage and high frequency response which would result if the measuring instruments were connected directly. Input Impedance: 200 megohms shunted by 6 mmf. Output Impedance: 300 ohms. Gains of 1.00, 10.0, and 100. Frequency Range from 5 cps to 150,000 cps within 2%. Background noise equivalent to 40 to 70 microvolts at the input.

Descriptive Bulletin Sent Upon Request

KEITHLEY INSTRUMENTS
1508 CRAWFORD RD. CLEVELAND 6, OHIO

ULTRA SENSITIVE D. C. AMPLIFIER

An Electronic Replacement For Sensitive Galvanometer Systems

The Model 53 Breaker-type D.C. Amplifier was developed for the measurement of d. c. and low frequency a. c. voltage in the microvolt and fractional microvolt region. It is compact, portable, and makes an excellent replacement for the suspension galvanometer. The output of the amplifier is sufficient to operate standard meters and recording devices directly.

It has been employed for the amplification of infra-red detectors, thermocouples, voltaic photocells, and the like, both in research and industrial applications.

Among the advantages of this amplifier are the following:

1. Noise level that approaches the theoretical limit imposed by Johnson noise.
2. Extremely low zero drift (less than .005 μ V after warmup).
3. Freedom from the effects of vibration such as found in moving vehicles.
4. Response characteristics permitting overall amplification flat from 0 to 10 cycles per second.
5. Reliability, as demonstrated by units which have been in continuous operation for several years.

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GLENBROOK · CONNECTICUT

More than 14 years of know-how and experience in every

PYROFERRIC IRON CORE

Pyroferric Iron Cores were first made in 1933 and the experience and know-how gained in each succeeding year are inherent in every powdered iron product today produced by the Pyroferric Company, including: a full line of standard sized Powdered Iron Screw-Type Cores of varying lengths, with standard threads, as well as a complete line of powdered iron cores, with and without inserts.

For Powdered Iron Cores to meet your specifications, address your inquiry to

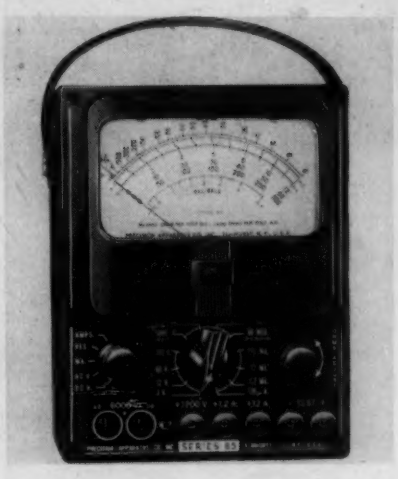
PYROFERRIC CO.

621 East 216 Street, New York City 67

recording work is designated model 77. Discrimination between front and rear is approximately 15 db at all frequencies. Response is within plus or minus 5 db from 70 to 10,000 cycles. Level is 62 db below 1 volt per dyne per square centimeter. Output can be selected from high impedance through 50, 200, or 500 ohms.

Maintenance Meter

PRECISION APPARATUS CO., INC., 92-27 Horace Harding Blvd., Elmhurst, L. I., N. Y. Series 85 bakelite-cased meter provides 34 self-



contained ranges up to 6,000 volts, 120 microamperes, 12 amperes, plus 70 db, and 60 megohms. Sensitivity is 20,000 ohms per volt d-c, and 1,000 ohms per volt a-c.

Suppressor Coils

BURNELL & Co., 45 Warburton Ave., Yonkers 2, N. Y. Now in stock are high-Q toroidal coils employed in the Scott dynamic noise suppressor. Type TC-1 800 (0.8 henry) and TC-

ELECTRIC SOLDERING IRONS

that are sturdily built for the hard service of industrial usage. Have plug type tips and are constructed on the unit system, with each vital part, such as heating element, easily removable and replaceable. In 5 sizes, and from 50 watts to 550 watts.

American Beauty

TEMPERATURE REGULATING STAND

This is a thermostatically controlled device for the regulation of the temperature of an electric soldering iron. When placed on and connected to this stand, iron may be maintained at working temperature, or through an adjustment on bottom of stand, at low or warm temperature.

For further information, write 115-1

AMERICAN ELECTRICAL HEATER COMPANY
DETROIT 2, MICHIGAN
established 1894

Cellusuede FLOCKED-FILM

. . . the Solution to Many Finishing Problems

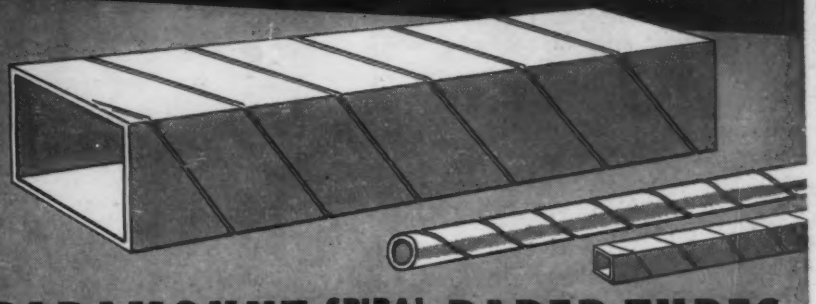
In instances where spraying Cellusuede Flock is not entirely practical, you will find flocked-film ready to do the job simply and effectively. Cellusuede Flocked-film is a pliant surface (of varying degrees of flexibility to meet certain conditions) evenly coated with millions of tiny flock fibres.

Film can be die-cut to meet specifications, and is easily applied with suitable adhesives. Sound deadening gaskets, box interior coatings, mar-proofing of external surfaces, and light-absorbing trim for backs of radio dials are but a few examples how Cellusuede Flocked-film can be used.

Precision-cut from new rayon filament in a wide range of lengths, Cellusuede Flock serves to increase the market value of thousands of products. Write today for booklet, color card, samples, prices, and other details.

CP
Cellusuede Products, Inc.
ROCKFORD, ILLINOIS

Over 1000 Sizes



PARAMOUNT SPIRAL WOUND PAPER TUBES

SEND FOR ARBOR LIST OF OVER 1000 SIZES

Convenient, helpful listing of over 1000 stock arbors. Includes many odd sizes of square and rectangular tubes. Write for Arbor List today. No obligation.

Square • Rectangular • Triangular
Round and Half-Round

With a wide range of stock arbors . . . plus the specialized ability to engineer special tubes . . . PARAMOUNT can produce the exact shape and size you need for coil forms or other uses. *Hi-Dielectric, Hi-Strength.* Kraft, Fish Paper, Red Rope, or any combination, wound on automatic machines. Tolerances plus or minus .002". Made to your specifications or engineered for YOU.

Inside Perimeters from .592" to 19.0"

PARAMOUNT PAPER TUBE CORP.
616 LAFAYETTE ST., FORT WAYNE 2, IND.
Manufacturers of Paper Tubing for the Electrical Industry

Make your tedious weighing job
Simple and Routine with
Roller-Smith
PRECISION BALANCES

SAVE TIME SAVE MONEY
IN ASSAYING — RESEARCH — PRODUCTION CONTROL — ANALYTICAL WORK

In the Manufacture of
Chemicals - Textiles - Lamp Filaments - Radio Tubes - Explosives - Watches - Paints - Biologicals

The Roller-Smith Precision Balance is universally used for weighing within the range of 3 mg to 150 grams. Everyday applications include the measurement of liquid surface tension, yarn numbering, counting extremely small parts by weight, assaying precious ores, weighing diamonds and specific gravity determinations.

The Roller-Smith Precision Balance is the result of careful research and painstaking design to produce a better means for *rapid weighing, quality control* and *uniformity* in the manufacture of your products.

The Roller-Smith Precision Balance is backed by over *40 years of research and development experience* in the engineering of fine products. Let **Roller-Smith** help you with your weighing problems.

Write now for the Roller-Smith Precision Balance Catalog.

ROLLER-SMITH
BETHLEHEM, PA.

Visit the Third National Instrument Exhibit, Convention Hall, Philadelphia, Pa., Sept., 13-17, 1948. See our display in Booth 515.

ROLLER SMITH

ELECTRICAL INDICATING INSTRUMENTS • AIRCRAFT INSTRUMENTS • SWITCHGEAR • AIR & OIL CIRCUIT BREAKERS • ROTARY SWITCHES
RELAYS • PRECISION BALANCES

1 2400 (2.4 henries) are available either cased or uncased.

Coaxial Line

PRODUCT DEVELOPMENT CO., INC., Arlington, N. J. A special pin-type Teflon-insulated coaxial line is available in RMA sizes together with fittings and accessories. The line has an essentially constant characteristic impedance with its frequency limitations well beyond 1,000 megacycles. Detailed data are available from the manufacturer.

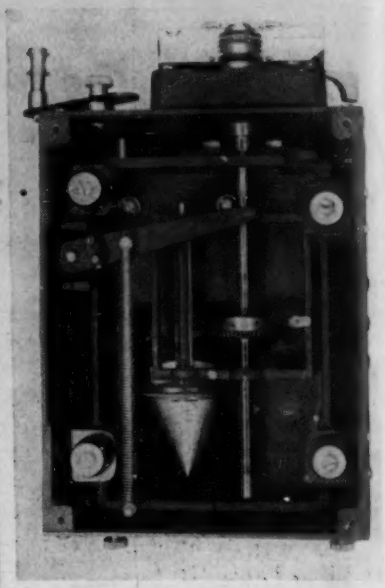
Horn Driver

RACON ELECTRIC CO., INC., 52 East 19th St., New York 3, N. Y. A special permanent-magnet horn driving unit has a rated capacity of 35 watts continuous duty and 60 watts peak. An Alnico V magnet is used in a watertight assembly.

Regulated H-V Supply

INSTRUMENT DEVELOPMENT LABORATORIES, 223 W. Erie St., Chicago 10, Ill. Model 1090 is a reactance-

A Really Good A C DRIVE



McElroy engineers have now completed design on the new AC drive shown above. This unit is the heart of the high speed equipment now being produced at the factory. It is used in the high speed recorder, the keying heads and in our high speed tape puller such as the CTP. Speed ratio is 50 to 1.

•

Precision machined, the unit will not vary in speed once set, regardless of normal load. A strobotac will show no variation in speed at loads up to 15 times the force required to break tape. Pulling as a tape puller, the rate will be within one percent.

•

An ingenious cradle increases friction with load, and a DC solenoid insures that the drive and idlers will be out of contact when the drive stops, thus preventing flats on the drive wheel.

Made at Telegraphers Lodge,
LITTLETON, MASSACHUSETTS
by the

McELROY MFG. CORP.

SALES DEPARTMENT
453 W. 47th St. • New York 19, N. Y.

Ceiling unlimited!

with the new

UNIVERSITY TWEETER

FULL RANGE RESPONSE TO THE LIMIT OF AUDIBILITY

Don't let your loudspeaker put a ceiling on the frequency response of your radio or phono equipment. Enjoy *full range* reproduction right up to 15,000 cycles by connecting one of these tweeters to your present cone speaker. Perfect for FM and the latest full frequency range recordings. Available in single or dual unmounted types and in walnut cabinet models. Prices from $20.00. Write today to UNIVERSITY LOUDSPEAKERS, INC., 80 South Kensico Avenue, White Plains, New York.

University Loudspeakers

PROJECTION TELEVISION!

30 KV RF POWER SUPPLY

Dimensions — Length 14', Width 11', Height 11¼'.

This unit has a low voltage supply separate from high voltage pack. Low voltage DC supply has control which enables you to vary voltage from approximately 12 KV to 40 KV. Unit has focus control built in for use with 5TP4 projection tube. Price, complete..... **$99.50**

F 1.9 TELEVISION PROJECTION LENS

Dimensions—Length 7", Diameter 4¼".

F 1.9 EF. 5 in. (127.0 mm). This lens incorporates in barrel a corrective lens for use with a 5TP4 projection tube. It is easily removable for use with flat type tubes. Lens can be utilized to project picture sizes from several inches to 7 x 9 feet. Made by Bausch & Lomb Optical Co.....Price **$125.00**

Include 25% Deposit With Order. Balance C.O.D.

Pioneers in Projection Television

SPELLMAN TELEVISION, INC.

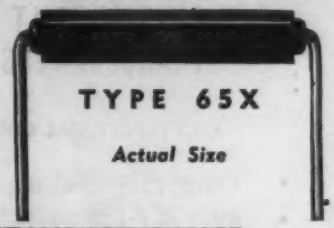
130 WEST 24th STREET • NEW YORK 11, N. Y.

MOLDED

S·S·White RESISTORS

The "All-Weather" Resistors

Of particular interest to all who need resistors with inherent low noise level and good stability in all climates



STANDARD RANGE

1000 OHMS TO 10 MEGOHMS

Used extensively in commercial equipment including radio, telephone, telegraph, sound pictures, television, etc. Also in a variety of U. S. Navy equipment.

HIGH VALUE RANGE

15 to 1,000,000 MEGOHMS

This unusual range of high value resistors was developed to meet the needs of scientific and industrial control, measuring and laboratory equipment—and of high voltage applications.

SEND FOR BULLETIN 4505

It gives details of both the Standard and High value resistors including construction, characteristics dimensions, etc. Copy, with Price List mailed on request.

S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. DEPT. R, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RESISTORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

KNOW ACTUAL RF POWER FED TO FM ANTENNA—WITH *MicroMatch*

Glancing at Micro-Match Model MM-200 indicator unit at WTHT's new FM transmitter is Charles S. Masini, Chief Engineer of station. Above, coupler unit in standard 1⅝" dia. coaxial line.

Micro-Match gives you direct, continuous accurate reading in kilowatts. Also gives precise, continuous reading of SWR of antenna system.

MICRO-MATCH models available for operation at 500 KC to 250 MCS, and power levels of 2 to 50,000 watts.

Write for complete descriptive literature

M. C. JONES ELECTRONICS COMPANY

96 North Main Street Bristol, Connecticut

Distributed outside continental U.S.A. by RCA International Division Radio Corporation of America.

For LONG TROUBLE-FREE OPERATION Specify

N·W·L

CUSTOM-BUILT TRANSFORMERS

AND ELECTRICAL COILS

From 10VA to 300 KVA Dry-Type Only, Both Open and Encased, 1, 2, & 3 Phase 25 to 400 Cycles.

Over 25 years' experience in the manufacture of specials at cost that compares favorably with standard types. Built-in quality proved by years of actual use.

PROMPT DELIVERIES!

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WINDING LABORATORIES
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HEAT RESISTANT WIRES FOR EVERY APPLICATION . . .

DESIGN ENGINEERS . . .

Do those new circuit designs present new wire problems?

Then check with Lewis Engineering for an economic solution and fast delivery. For twenty years we've successfully been solving the heat and age resistance wire problems of industry. We don't stock wire—we make it to your specs—for an experimental run or for the production line. If you're designing in the electronic, electrical or appliance field . . .

HEATING UNITS
HEATING ELEMENTS
RESISTANCE LINE CORD
THERMOCOUPLE WIRE
ASBESTOS LEAD & FIXTURE WIRE
INSULATED RESISTANCE WIRE
FIBERGLAS INSULATED WIRE
WIRE TO ANY SPECIFICATIONS

Let Lewis Build The Wire For You

Send your electronic control, communications or appliance wiring specifications for a recommended solution by our engineers.

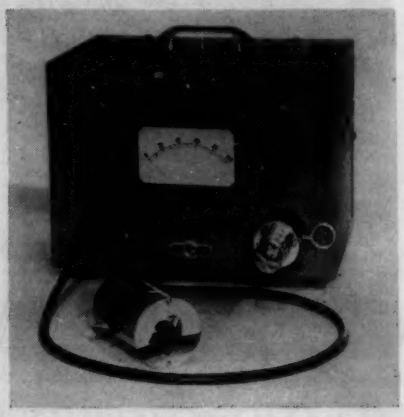
FOR A TRIAL ORDER OR A CARLOAD *consult*

THE LEWIS ENGINEERING CO.
Wire Division
NAUGATUCK CONNECTICUT

regulated d-c supply for use by research physicists. Output varies less than 0.01 percent with input variation between 90 and 130 volts. Output voltage is continuously variable between zero and 5,000 volts d-c.

Milliwattmeter

ROWE ENGINEERING CORP., 2422 North Pulaski Road, Chicago 39, Ill. Type MW55 vhf and uhf milliwattmeter can be used in the range from 50 to 500 megacycles to measure powers in the order of 2 to 1,000



milliwatts. Filament brilliance comparison and a thermistor bridge arrangement are used. Power indications are from meter readings and a calibration chart. Accessory probes provide a variety of methods of circuit coupling.

Bombarder

S CORRUGATED QUENCHED GAP CO., 107 Monroe St., Garfield, N. J. A new 3½ kw bombarder or high-fre-

KENYON TRANSFORMERS

Engineers specify Kenyon Transformers for dependable performance. Famous for conservative ratings and rugged construction, Kenyon transformers are preferred for long, trouble-free service in quality equipment.

TERMINAL carries a complete stock of Kenyon transformers and chokes for power and audio requirements.

Catalog on request.

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Distributors of Electronic Equipment
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PLN SERIES—Designed for NE-51 Neon Lamp

Features

- THE MULTI-VUE CAP
- BUILT-IN RESISTOR
- 110 or 220 VOLTS
- EXTREME RUGGEDNESS
- VERY LOW CURRENT

Write for descriptive booklet

The DIAL LIGHT CO. of AMERICA
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FLEXIBLE SHAFTS

that carry power around any corner have many new uses in peace-time developments. Faithful, dependable power drives or remote control in airplanes, automobiles, radio, and many other commercial products.

Shafts made to your specifications. Our engineering department will work out your particular power problem without obligation.

Write today for Manual D

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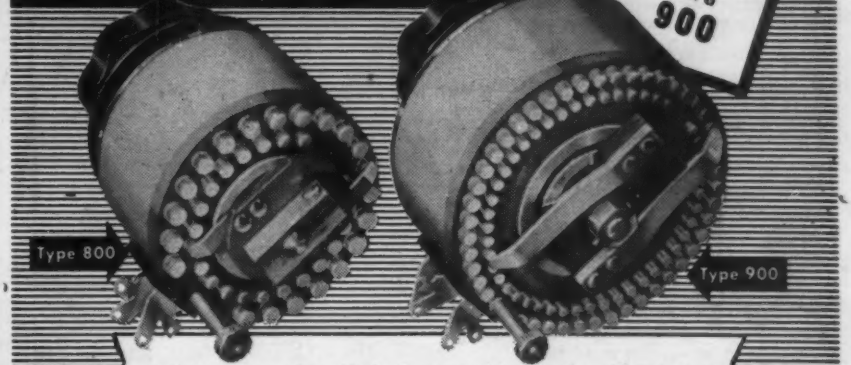

"New Times—New Modes", says old proverb. These new attenuators were born to meet new war-created demands. They represent a new medium frame size: Type 800 (2¼" dia.) and a larger size: Type 900 (3" dia.). The Type 800 is supplied as potentiometer, rheostat, ladder and T-pad up to 20 steps. The larger size Type 900 is similarly furnished with up to 45 steps. Write for new bulletin.

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Manufacturers of Precision Electrical Resistance Instruments
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quency induction heater operates from a 220-volt line. The apparatus weighs 300 pounds.

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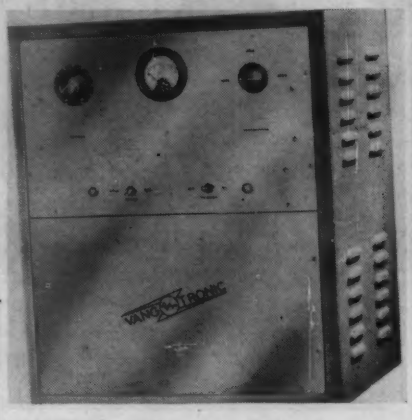
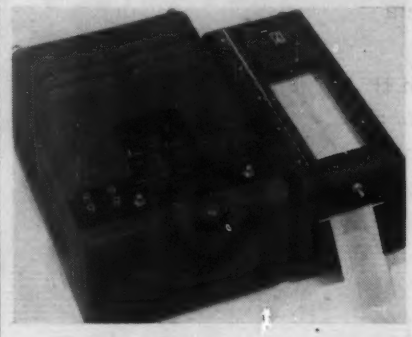
VANGTRONIC CORP., 237 John St., Bridgeport 3, Conn. A-c spot welders can be converted to the stored-



energy type for spot-welding aluminum and other high conductivity metals. The unit illustrated gives speeds from 30 to 180 spots per minute.

Strain Amplifier

BRUSH DEVELOPMENT CO., 3405 Perkins Ave., Cleveland 14, Ohio. Model BL-310 strain amplifier designed for use with the direct inking oscil-



lograph illustrated can be used with Baldwin SR-4 strain gages, Statham Lab pickups, and many other types of resistance-sensitive gages. Specifications are in catalog sheet F-376.

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GENERAL ELECTRIC CO., Schenectady 5, N. Y. A new photoelectric recording wattmeter for analysis of

a Pocketful of PRECISION Series 40

Compact Wide-Range Circuit Tester

Self-Contained to 6000 V
5 Megs, 600 MA, +70 DB,
with full size
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Series 40 Complete with ohmmeter batteries and test leads.
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ALL RANGES are SELF-CONTAINED.
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See this new "Precision" Test Set now on display at all leading radio parts and equipment distributors, or write directly for the Precision 1948 catalog describing the complete Precision line of quality Electronic Test Instruments for all phases of modern radio-electronics — A.M., F.M. and TV.

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One of a series *of messages to help you increase your understanding of business paper advertising, and its effect on your business.*

Maybe "more production" isn't the answer to all our problems

AMERICAN INDUSTRY is already producing at almost double its pre-war rate. Yet with labor and material costs at an all-time high, the experts insist that we must produce still more goods, faster, more efficiently, if we are to avoid another boom-and-bust cycle.

We'll buy that—as far as it goes.

But let's never lose sight of the fact that production is only half the problem. Because for every increase in our rate of production, there must be a comparable rise in our *rate of sales.*

Actually, of course, there is no such thing as producing goods at a profit. Goods are *sold* at a profit—yes. And while production line savings are vitally important, it is of equal importance to keep down the cost of *manufacturing sales.*

That is the function of *mechanized selling*—to produce sales on a mass production basis, and at the lowest possible cost per unit. Translated into more familiar terms, it simply means advertising to the right market, in the right way, at the right time.

Like the machine on the production line, good advertising is a multiplier of men's efforts, for it enables us to produce (and *earn*) far more than we could alone. And when it goes to work in business papers — with their tremendous concentration of hand-picked readers—advertising becomes the most efficient machine at our disposal for *manufacturing sales at a profit.*

What are the ten ways to measure the results of your business paper advertising? You'll find the answers in a recent ABP folder, which we'll be glad to send you on request. Also, if you'd like reprints of this advertisement (or the entire series) to show to others in your organization, you may have them for the asking.

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is one of the 129 members of The Associated Business Papers, whose chief purpose is to maintain the highest standards of editorial helpfulness—for the benefit of reader and advertiser alike.

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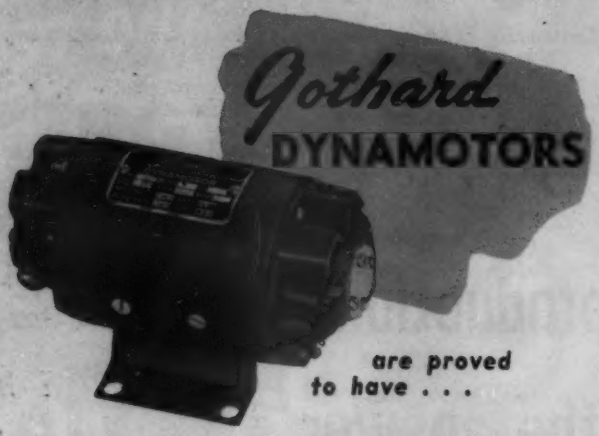

are proved to have . . .

Prompt Delivery

- Added safety factors for overloads.
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- Double varnish impregnation of windings.
- Precision machining.
- Rugged, lightweight.
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STANDARD SIGNAL GENERATOR

2 to 400 MEGACYCLES

MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

FREQUENCY ACCURACY ±.5%

OUTPUT VOLTAGE 0.1 to 100,000 microvolts

OUTPUT IMPEDANCE 50 ohms

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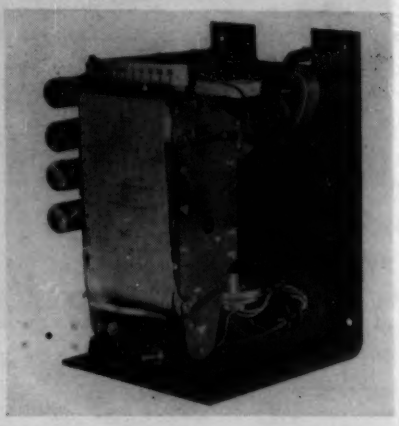
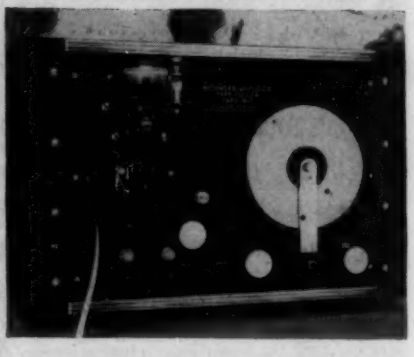


special power loads can be used on d-c or a-c up to 10,000 cycles. The instrument comprises a high-speed photoelectric recorder and a new wattmeter measuring unit. Charts speeds of a half inch per hour up to 72 inches per minute can be obtained.

Tape Recorder

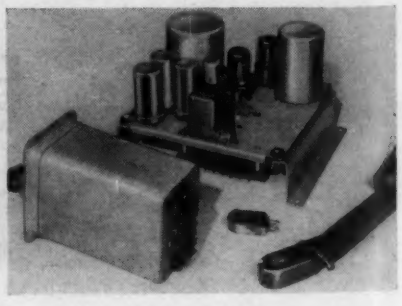
McELROY MFG. CO., Telegraphers Lodge, Littleton, Mass. A new inked tape recorder is capable of



Morse code speeds up to 1,500 words per minute. Tone input is accepted by the self-contained amplifier. A siphon inkwell is used.

Diamond Pickup

GENERAL ELECTRIC CO., Syracuse, N. Y. A diamond stylus variable reluctance pickup with either 2.5 or



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Insure Better Reception!

Actual operation proves the Premax FM-130 Adjustable Dipole Antenna with its exclusive 3d dimensional adjustment materially reduces man-made electrical noise in FM reception.

This Antenna has been found to be the dealer's and service man's solution to poor reception because he can adjust this antenna to cope with local conditions and cancel out noise and reflected signals.

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Premax Products

Div. Chisholm-Ryder Co., Inc.
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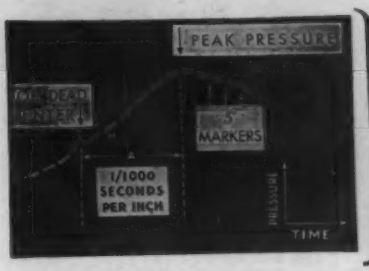
Have you ever seen the INSIDE of an EXPLOSION?

or the rate of engine flame propagation



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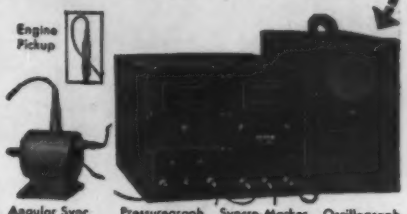
PRESSUREGRAPH with Syncro-Marker

Reproduces on oscillograph screen, accurate picture of pressures during and after explosion, relates pressure variations to time, top dead center, angular velocity, etc. Also accurate tracing of rate of flame propagation with relation to top dead center and peak pressure. See pressure-time characteristics of automotive, jet and Diesel engines, also compressors, pumps, etc. Operates over range from static up to 10,000 cycles at pressures from 0 to 10,000 lbs.



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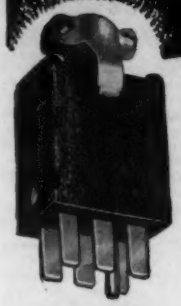
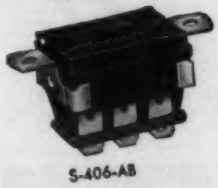


P-406-CCT



S-406-AB

Socket contacts phosphor bronze cadmium plated. Plug contacts hard brass cadmium plated. Insulation molded bakelite. Plugs and sockets polarized. 2, 4, 6, 8, 10, 12 contacts. Steel caps with baked black crackle enamel.

Catalog No. 16 gives full information on complete line of Jones Electrical Connecting Devices — Plugs, Sockets and Terminal Strips. Write

HOWARD B. JONES DIVISION
Cinch Mfg. Corp.
2460 W GEORGE ST CHICAGO 18 ILL

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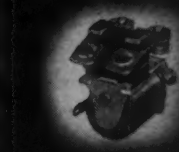

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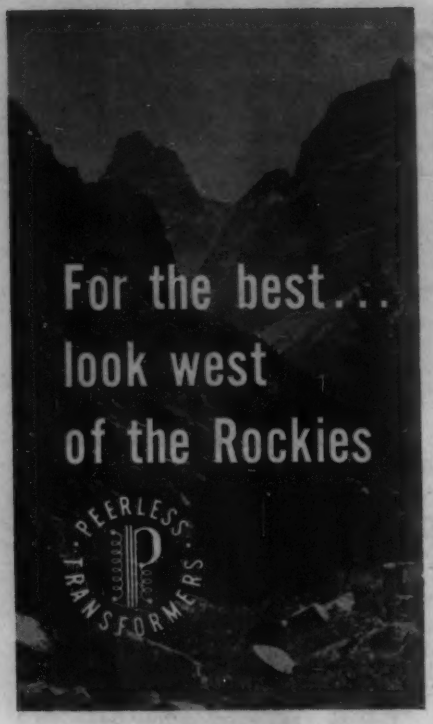
Type TG Type DOS Type DO

ENGINEERING "KNOW-HOW"



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Literature

Wire Recording. Wire Recording Corp. of America, 1331 Halsey St., Brooklyn 27, N. Y., has issued a pamphlet on Wireway, the combination recorder and playback. Vital features and various uses are set forth.

Conduit Fittings. Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif. Catalog sheets are now available showing AN3060 45-degree conduit coupling, AN3064 box connector, and AN3068 conduit coupling adapter.

Tube Applications. Radio Corp. of America, Harrison, N. J. Application notes on the new Special Red tubes, a-c/d-c f-m/a-m receivers, preventing kinescope damage, and the use of miniature tubes in stagger-tuned i-f circuits have recently been printed.

Resistance Wire. Wilbur B. Driver Co., 156 Riverside Ave., Newark 4, N. J. All types of resistance wire manufactured by the company are described and their prices given in a new resistance handbook recently published.

F-M Broadcaster. Radio Engineering Laboratories, Inc., 35-54 36th St., Long Island City 1, N. Y., has issued bulletin 5012A with complete details of their 10-kw f-m broadcast transmitter employing a Quadriline amplifier.

Vibration Detection. Consolidated Engineering Corp., 620 North Lake Ave., Pasadena 4, Calif. Bulletin CEC-1510 covers the model 4-102 vibration pickup and the type 1-110B vibration meter. Complete

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SYNCHRONIZING GENERATOR
Model PT 101—Television

FEATURES
- Built-in 3" oscilloscope with synchronized sweeps for viewing Timing and Video Output pulse wave forms.
- Synchronized marker system for checking pulse width and rise time.
- Extreme stability, insured by deriving all pulses from leading edge of master oscillator pulse.
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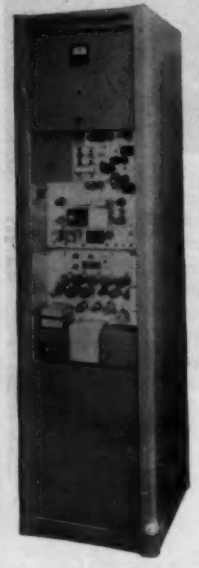

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Model PT 102

- Composite Video Signal
- Wide Band Video Amplifier, 6 DB down at 10MC
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INPUT: Vertical and Horizontal Driving pulses. Camera and Kinescope Blanking Pulses.

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Television engineers and consultants to the nation's great television stations.

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RACON'S Hi-Frequency TWEETER

- Simply connect this tweeter in parallel with your present speaker, using a cross over network, and you will obtain perfect sound reproduction throughout the **entire** audible frequency range.
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- Level response 500 to 14,000 cps with cutoff at 18,000 cps. Uses 17 oz. Alnico V magnet. Continuous power handling capacity 8 watts enabling its use with multicellular horns if desired.

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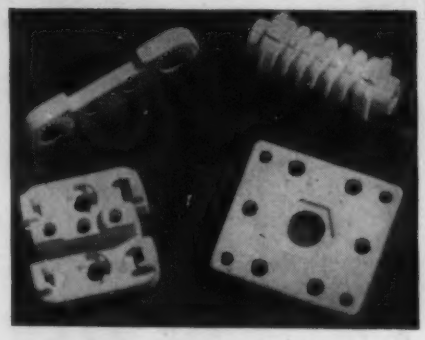

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Compressive Strength	98,000	lbs. per square inch
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Flexural Strength	10,500	lbs. per square inch
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Dielectric Strength	235	volts per mil
Dielectric Constant	6.42	Frequency of 1 megacycle
Loss Factor	7.90	Frequency of 1 megacycle
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Bulk Specific Gravity	2.664%	
Density (from above gravity)	0.096	lbs. per cubic inch
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Softening Temperature	2.350°F.	
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Design engineers and manufacturers in the radio, electrical and electronics fields are finding in LAVITE the precise qualities called for in their specifications . . . high compressive and dielectric strength, low moisture absorption and resistance to rot, fumes, acids, and high heat. The exceedingly low loss factor of LAVITE plus its excellent workability makes it ideal for all high frequency applications.

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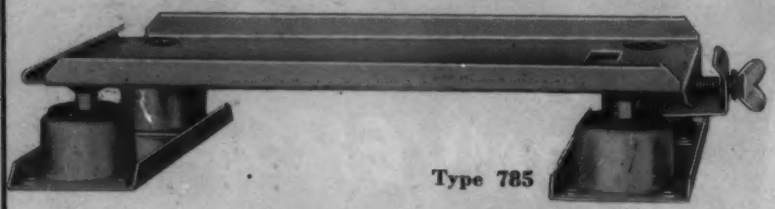

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Standard MTS Size Aircraft Mounting Rack with revolutionary air-damped vibration isolators

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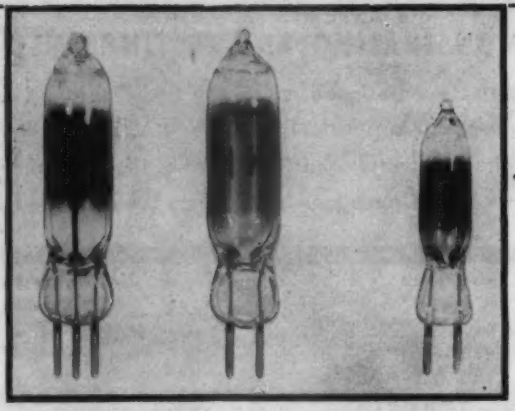

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DESIGN ENGINEERS are showing ever increasing interest in Continental Lead Sulfide Cells because of their compactness, high sensitivity and good frequency response. Ideal for Sound Reproduction, Burglar Alarms, Door Openers, Tabulating Machines, Phonograph Pickups, Controls and Counters and many other types of devices and equipment. These Continental photo-conductive tubes are your assurance of steadier, more dependable performance.

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specifications for both instruments are given.

Engineering Bulletin. American Phenolic Corp., 1830 South 54th Ave., Chicago 50, Ill., will send upon request its monthly engineering bulletin of technical information. Each month's issue is devoted to one major subject in detail. It can be filed in a standard three-ring binder.

Crystals. Clark Crystal Co., Marlboro, Mass. Four new series of crystals are described complete with technical data on a single sheet. Various types of each series are treated in tabular form.

Motor Control Sheets. Square D Co., 4041 N. Richards St., Milwaukee 12, Wis. A series of sheets is now available for insertion in the electric motor control catalog. Revised terms of sale and prices as well as new products are included.

Projection Television. Spellman Television Co., 2898 Jerome Ave., New York 58, N. Y. Five catalog sheets describing projection television components sum up what is necessary to convert certain sets for large-audience viewing.

Products Reference Listing. Federal Electric Products Co., 50 Paris St., Newark 5, N. J. The latest edition of the Federalog may now be obtained on request. It offers a quick reference listing of motor controls, safety switches, switch boards, and is profusely illustrated.

RCA Index. RCA Laboratories, Princeton, N. J. Technical papers appearing in all publications by authors employed at RCA are listed for the year 1947 in Vol IIb. The booklet supplements a previous similar listing for the period 1919 to 1945.

Instrumentation. Statham Laboratories, Inc., 8222 Beverly Blvd., Los Angeles 36, Calif. The first issue of a bi-monthly publication

TERMINALS *for* ELECTRIC WIRES

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IRN magnetic iron powders (Mepham hydrogen reduced) are available in 10 different types for high-frequency cores, core material, tele-communication and magnetic applications. . . . All are described in a revised technical bulletin, containing 28 pages of comprehensive data, including performance graphs and engineering reference material of value to designers, manufacturers and users. Your copy of this bulletin will be mailed on request.

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"Instrument Notes" promises short articles on theory and practice interesting to users and designers of precision instruments. The pamphlet will be sent free upon request.

Insulation Material. New England Mica Co., Inc., Waltham, Mass. A four-page folder discusses Super-Nemcoite, a composite bonded mica insulation for use in electrical equipment and machinery.

Step-Down Transformers. Electran Mfg. Co., 4587 N. Elston Ave., Chicago 30, Ill. Bulletin 47A gives a four-page description of air-cooled step-down transformers for power circuit installations. Ratings, physical data and wiring diagrams are included.

Control Unit. R-S Products Corp., Wayne Junction, Philadelphia 44, Pa., recently published catalog No. 27 on the Leveltronic relay, designed for basic applications in the control of liquid level, interface, pressure and temperature.

Electrical Insulation. Insulation Manufacturers Corp., 565 W. Washington Blvd., Chicago 6, Ill. A single-sheet mailing piece describes the outstanding features of Dieflex tubing and sleeving. The products are designed to answer specific manufacturing and use problems of electrical insulation.

Insulation Tester. Herman H. Sticht Co., Inc., 27 Park Place, New York 7, N. Y. Bulletin 441 describes the B-6 Megohmer, a non-cranking tester with a steady test potential. Source of power are two No. 6 dry-cell batteries which are stepped up to 500 volts d-c by means of a special vibrator-transformer circuit. Also featured on the instrument's face is a triple-color grading scale classifying insulation as good, fair or doubtful.

Intermodulation Measuring. Western Electric Co., 233 Broadway, New York 7, N. Y. A six-page

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Hermetically sealed in ½" diameter glass tubes, Bradley SE 6M high voltage selenium rectifiers are rated at 5 ma D.C. They are polarized for fuse clip-type mounting. Available for 1000, 2000, 3000 and 4000 volts peak inverse. Bradley engineers can quickly specify the right type of selenium or copper oxide rectifier for your need.

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SIMPLIFY PHOTO CELL CONTROL

Luxtron* photo cells convert light into electrical energy. No external voltage is required to operate meters and meter relays directly from Bradley photo cells, improving control over your processes, reducing your costs. Housed model shown. Many different sizes and shapes, mounted and unmounted.

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Illustrated literature, available on request, shows Bradley's full line of photo cells and copper oxide and selenium rectifiers.

Write for "The Bradley Line"

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folder describes two intermodulation instruments, the RA-1258 signal generator and the RA-1257 analyzer, together with their mode of operation.

High-Vacuum Pumps. W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill. Duo-Seal pumps, capable of producing a vacuum of 0.05 micron and better, are described and illustrated in a 32-page, slick-papered, spiral-bound booklet.

Relay Catalog. Potter & Brumfield Sales Co., 549 West Washington Blvd., Chicago 6, Ill. Relays and electrical timing devices are listed in new catalog 148. Power, plate-circuit, latching, and midget types are exhaustively described.

Coils. J. W. Miller Co., 5917 South Main St., Los Angeles 3, Calif. R-f and i-f coils, radio interference filters, special chokes, dividing-network coils, tower-lighting chokes, and carrier-circuit coils are among the products listed in the 36-page catalog 48.

Radio Generator. American Bosch Corp., Springfield 7, Mass., offers a reprint of one of its advertisements describing the type GRB mobile radio generator which has a 45-ampere output at a speed of from 10 to 15 mph. List price complete with regulator, harness and single-groove pulley is $125.

D-C Power Supply. Rowe Engineering Corp., 2422 North Pulaski Road, Chicago 39, Ill. Two sides of a loose-leaf perforated sheet give a thorough treatment of the type IPS10000 10-kv d-c power supply. Applications, general description, operation and circuitry, and technical data are given.

Precision Instruments. Associated Research, Inc., 231 S. Green St., Chicago 7, Ill. Many types of precision testing instruments are listed in a new catalog. Among these are the Keeler Polygraph (lie detector). Technical and engineering data are also included.

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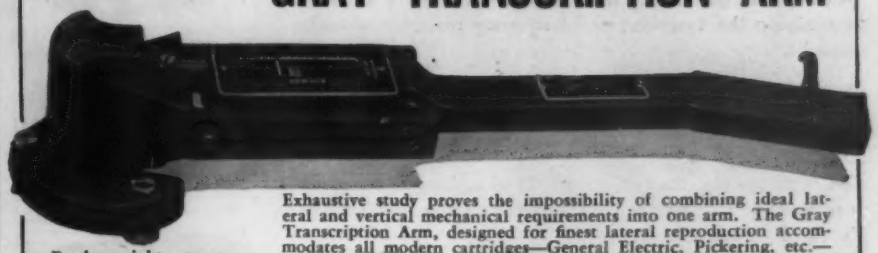

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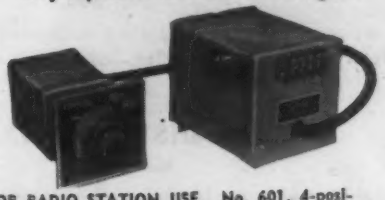
Gray Equalizer For G.E. Cartridge



FOR RADIO STATION USE. No. 601, 4-position Equalizer (Flat, N.A.B., etc., etc.) expertly engineered for use with the G.E. Variable Reluctance Cartridge Matches pick-up to microphone channel. Adopted by radio networks. Complete $42.50.

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Model 250

A device for generating a test signal particularly useful for examining the transient and frequency response of audio circuits.

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An accurate and convenient means of making direct measurements of unknown audio frequencies up to 30,000 cycles. Integral power supply.

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A source of stable, accurately calibrated frequencies between 30 and 30,000 cycles. Self-contained power supply.

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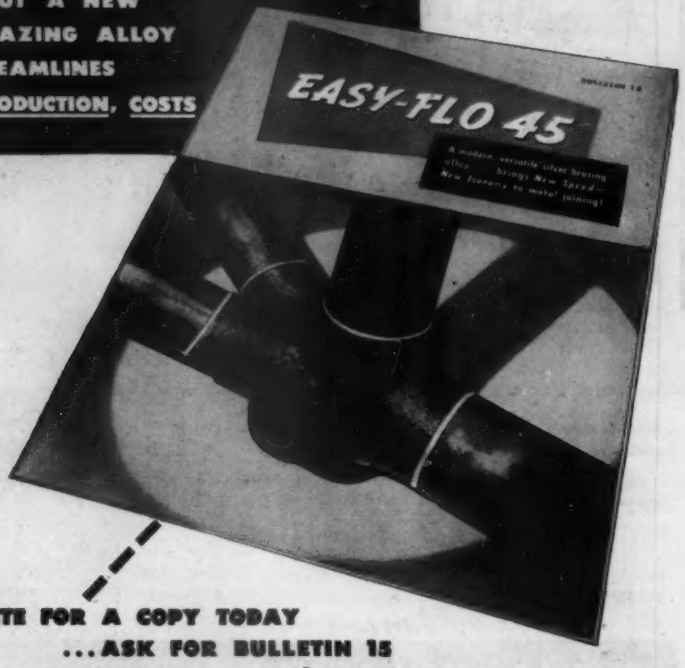

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pressed a button starting the tape, at the end of which she answered the caller.

Frequency Designations

AT THE meeting of the Wave Propagation Committee of the IRE on February 2, the following two motions were passed:

(1) The present system of naming bands (h-f, vhf, uhf) is unsatisfactory and should be discouraged.

(2) Frequency bands should be designated by the characteristic of the logarithm to the base 10 of the frequency in cycles per second. Thus

FREQUENCY	BAND NO.
1 cps — 10 cps	0
10 cps — 100 cps	1
100 cps — 1,000 cps	2
1 kc — 10 kc	3
10 kc — 100 kc	4
100 kc — 1,000 kc	5
1 mc — 10 mc	6
10 mc — 100 mc	7
100 mc — 1,000 mc	8
1 kmc — 10 kmc	9
10 kmc — 100 kmc	10

Spring Technical Conference

PROGRAM of the Spring Technical Conference of the IRE, held in Cincinnati, Ohio, April 24, is as follows:

10:00 a. m.—Moderator—W. C. Osterbrock of the U. of Calif.
Cathode Compensation of Video Amplifiers, by A. B. Bereskin of the U. of Calif.
Television Test Equipment for the Receiver Designer, by Jerry Minter of Measurements Corp.
Television Transcription by Film, by T. T. Goldsmith of Allen B. DuMont Lab.
Microwave Radio Relay Facilities of the Bell System, by J. Harold Moore of A. T. & T. Co.
2:15 p. m.—Moderator—L. M. Clement of the Crosley Div., Avco Mfg. Corp.
Overall Systems Problems in Improving Television Quality, by Robert E. Shelby of National Broadcasting Co., Inc.
A Symposium on Television Tuners, by Sarkes Tarzian of Tarzian Associates; J. A. Stewart of General Instrument Corp.; John Rankin of Belmont Radio Corp.; and Nelson Case of Hallicrafters Co.
The 44-216 Megacycle Inductuner, by Myron F. Melvin of P. R. Mallory & Co. Inc.

Supplement to Study Guide

AS THE FCC revises its commercial radio operator examinations it will issue supplements to its study guide on the subject. Supplement No. 1, now available at the Commission's field examination offices and at its Washington offices, contains 114 additional questions dealing with new material in Element 4 (advanced radio-telephone theory and practice) of the examination to be held on July 1. Approximately half

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Toroidal and Sinusoidal

For use in computing and analyzing devices; generation of low frequency saw tooth and sine waves; controls for radio and radar equipment; position indicators; servomechanisms; electro medical instruments, measuring devices—telemetering; gun fire control where 360° rotation, high precision and low noise levels are essential.

The type RL14MS sinusoidal potentiometer is illustrated. It is wound to a total resistance of 35,400 ohms and provides two voltages proportional to the sine and cosine of the shaft angle. It will generate a sine wave true within ±.6%. Overall dimensions are 4⅜" diameter x 4 11/32 long plus shaft extension ¼" diameter x 1¼" long.

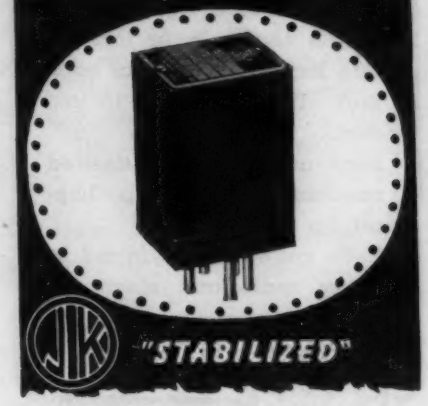
Write for Bulletin F-68

THE GAMEWELL COMPANY

Newton Upper Falls 64, Massachusetts

GAMEWELL

Crystals for the Critical



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JK STABILIZED JKO-3

This is a crystal oven designed to accommodate the following JK crystals: H7, H15, H17 and others. Operating temperature is adjustable and temperature stability is plus or minus 1° C. Heater is 6.3 volt and consumption is approximately 1 amp. Others on special order.

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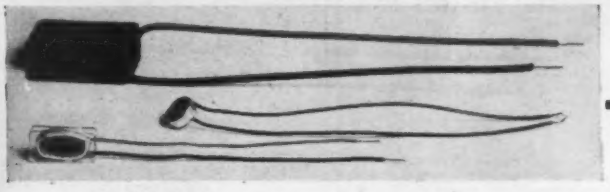

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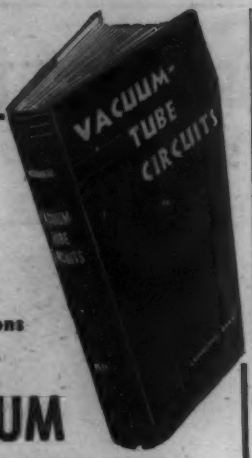

A basic book for communications technicians

VACUUM TUBE CIRCUITS

By LAWRENCE B. ARGUIMBAU,
Assistant Professor,
Department of Electrical Engineering,
Massachusetts Institute of Technology

This book has been written in answer to the need for up-to-date literature on the subject of vacuum tube circuits. The selection of material contained in the book, and its presentation, have been carefully designed to cover the problems encountered in the field of communications.

The most recent information on the subject has been compressed and edited so that topics of major importance receive more detailed attention. The first chapter comprises an overall introduction with a comprehensive presentation of the interrelation of the various component parts to be discussed.

The treatment is developed carefully from simple circuits to those of a more complex nature. Emphasis is given to frequency modulation as opposed to amplitude modulation. In view of the rapid developments in the field of television, the book also includes much basic material on transient response and on the generation of micro-waves. Unusually full explanations throughout insure readability and understanding.

Contents: Radio Communication; Diodes and Rectifiers; Triodes, Pentodes, and Linear Amplifiers; Transient Response of Video Amplifiers; Amplitude Modulation and Tuned Amplifiers; Power Amplifiers; Oscillators; Inverse Feedback; Amplitude Modulation; Frequency Modulation; Pulses and Television; Micro-waves.

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of the new questions deal with f-m and television. Other examination elements will be covered in different supplements to be issued from time to time and furnished without cost.

Mail requests for supplements should indicate the examination elements the person wishes to study. Such requests are to be addressed to the Secretary, Federal Communications Commission, Washington 25, D. C.

Copies of the study guide itself may be purchased from the Superintendent of Documents at $.25.

RMA-IRE Spring Meeting

THE TECHNICAL program for the RMA-IRE spring meeting, held April 26-28 at the Hotel Syracuse, Syracuse, N. Y., is as follows:

MONDAY, April 26—An Integrated Line of FM Broadcast Transmitters, by J. E. Young of RCA.

A New FM Antenna, by H. J. Howland of The Workshop Associates, Inc.

The Right Way to an RMA Standard, by L. C. F. Horle, Chief Engineer of RMA Engineering Department.

Audio Frequency Measurements, by H. H. Scott of Herman Hosmer Scott, Inc.

TUESDAY, April 27—Spectrum Analysis Applied to a Variable Speech Amplifier, by R. Whittle of Federal Telephone & Radio Corp.

Development and Application of Railroad VHF Communication Equipment, by A. A. Curry of Farnsworth Television & Radio Corp.

A New Design of Point-to-Point Communication Equipment, by Coleman London of Westinghouse Electric Corp.

The Engineer and his Neighbor, by E. Finley Carter of Sylvania Electric Products Inc.

WEDNESDAY, April 28 — Lighthouse Tube Life, by H. D. Doolittle of Machlett Laboratories, Inc.

A Review of Crystal Saver Circuits for VHF Receivers, by Dr. H. W. Hedeman, Jr. of Bendix Radio, Division of Bendix Aviation Corp.

Commercial Applications of Klystrons,, by Coleman Dodd of Sperry Gyroscope Company, Inc.

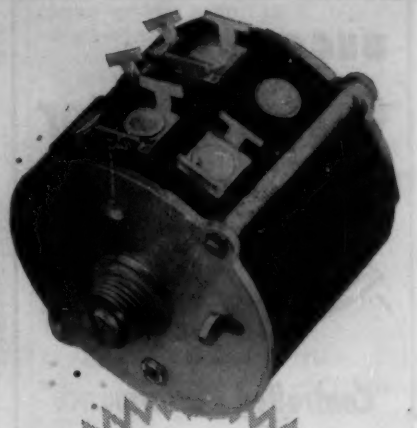
A Broad Band Microwave Relay System Between New York and Boston, by A. L. Durkee of Bell Telephone Laboratories, Inc.

Radar as an Aid to Airline Navigation, by R. C. Jensen of General Electric Company.

Sunspots Affect Radio

SCIENTISTS at the National Bureau of Standards report that the peak of sunspot activity for the present 11-year cycle has passed. The trend will be downward for about seven years and will have an important effect on worldwide radio communication.

As the number of sunspots de-



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For three or more controls in tandem, Clarostat Type 42 is the logical choice.
Bakelite cases nest and lock together for a virtually solid casing. Metal end-plates and tie-rods insure rigidity.
Single shaft passes through and locks with rotor of each unit. Up to 20 units in tandem! No back lash.
Each unit wound to desired resistance, taper, tap, hop-off, for given circuit.
Such controls now found in many radio and electronic circuits.

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clines there is less reflection of the higher radio frequencies from the ionosphere back to the earth. The first effects will be felt on the 50-mc band where dependable range will be reduced to about 75 miles in a few months. The overall effect at sunspot minimum will narrow the band to an upper limit of about 20 mc for continent-to-continent transmission.

New England IRE Meeting

THE SECOND annual New England Radio Engineering Meeting sponsored by the North Atlantic Region of the IRE will be held on Saturday, May 22, at the Hotel Continental, Cambridge, Mass.

Plans include technical sessions, manufacturers' exhibits, trips to points of current electronic interest, a luncheon and a banquet.

Four of the six technical papers will be:

A Standard Signal Generator for FM Broadcast Service, by Donald B. Sinclair of General Radio Co.

The Boston-New York Microwave Radio Relay Link, by a representative of Bell Telephone Laboratories.

Certain Aspects of Pulse Modulation, by E. R. Kretzmer of the Research Laboratory of Electronics.

Studio Acoustics, by Leo Beranek of MIT.

New England members will receive a detailed program and registration card through the mail. Nonmembers can obtain this material and other information by addressing the registration chairman, Harold Dorschug, Radio Station WEEI, 182 Tremont St., Boston, Mass.

Canadian IRE Convention

The Canadian IRE Convention, to be held at the Royal York Hotel, Toronto, April 30 and May 1, will include technical sessions and an exhibition of component parts, test apparatus and allied products. The tentative program of papers is as follows:

Narrow Beam Radar Recording Altimeter, by B. J. McCaffrey of National Research Council, Ottawa.

Frequency Allocations, by L. E. Coffey and C. J. Acton of Department of Transport, Ottawa.

Industrial Electronics, by J. T. Thwaites of Canadian Westinghouse Co., Ltd., Hamilton.

A Direct Reading Phase Monitor, by D. F. Wright of Canadian Marconi Co., Montreal.

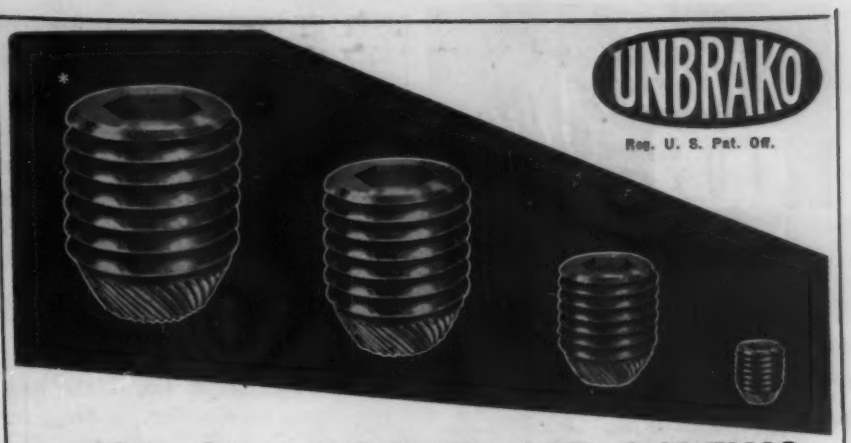
F. M. Field Intensity Measurement, by J. E. Hayes of Canadian Broadcasting Corp.

Recent Developments in Facsimile, by F. A. Hester of Radio Inventions, New York.

The Reproduction of Sound, by E. O. Swan of Radio Station CKEY, Toronto.

New Measuring Equipment in the Radio Industry, by B. DeF. Bayly of Bayly Engineering Limited.

25 Cycle Operation of Television Re-



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Knurling of Socket Screws originated with "Unbrako" in 1934.*

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All of our patented "Unbrako" Set Screws, regardless of point, are excellent Self-Lockers—so, if it is imperative that your Set Screws stay-put, write us—because we can lock most any Set Screw application.

OVER 45 YEARS IN BUSINESS

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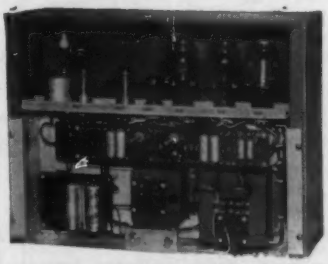
New!

RMC aural AMPLIFIERS

TYPE 115 SERIES



Interior view. Note front serviceability feature.

Exterior view

Here is a three-stage, push-pull throughout Amplifier with high gain, low noise and distortion, the result of engineers' twenty years' experience, and long study of customers' needs before perfection. Designed for many uses in high quality sound systems, such as: (1) Reproducing systems for Vertical and Lateral disc reproduction. (2) Public address system working from Microphone to Speakers. (3) Used with bridging input attenuator as Monitor Amplifier for broadcast stations. (4) With bridging attenuator as Subscriber Amplifier for wired music installations. (5) For sound distribution systems in locations where available space is limited. Installation, service and maintenance operations all facilitated from front of Type 115 Amplifier. Can be permanently installed in wall cabinet; or for standard rack mounting.

TYPICAL ELECTRICAL CHARACTERISTICS

Gain 100 DB maximum with provision for reduction in gain to 64 DB.

Frequency Response plus and minus 1 DB over range 30 to 16,000 cycles.

Operates from 150 or 600 ohm source.
Operates into 4 ohm (2 to 8 ohm).
Operates into 16 ohm (8 to 32 ohm).
Operates into 150 ohm (75 to 300 ohm).
Operates into 600 ohm (300 to 1200 ohm).

Output power approximately 15 watts, 5% total harmonic distortion.

Output noise equivalent to an input signal of minus 120 DB below .006 W. at maximum gain unweighted (approx. minus 130 DB weighted). Frequency characteristic plus and minus 1 DB over the range 30 to 16000 cycles.

Sold through local Jobber

Write for Bulletin A1-6

Export: Rocke International Corporation, 13 East 40th Street, New York 16, N. Y.

RADIO-MUSIC CORPORATION

PORT CHESTER • NEW YORK

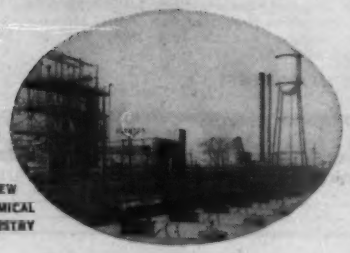
Silicone News

DC

This is your party, too!

Now we're five years old. We can look back with some pride on what we've accomplished in that time. We look with equal satisfaction on the work done by our customers. Without their initiative no new material could have been adapted to so many different uses in so short a time. Working together, we have built a new chemical business to serve all industry.

1943 — A PLOT OF GROUND



1948 — A NEW CHEMICAL INDUSTRY

1943—We started with a legacy of some silicone fluids, 2 electrical insulating resins, a valve lubricant and an ignition sealing compound.
1948—We are now producing 60 different Dow Corning Silicone Products in the form of fluids and oils, greases and compounds, resins and varnishes and Silastic* all of which will do many things no other materials can do.
1943—We had essentially one customer and his name was Uncle Sam.
1948—Among our 7500 industrial customers are concerns in almost every major industry. Recently, we entered the consumers' market to bring silicones home to John Q. Public.
1943—We started to build a plant and a main office in Midland, Michigan.
1948—We have a large plant, now almost twice its original size, working full time to supply you with the silicone products you have come to depend upon. It's the first plant of its kind ever built. To pace our increasing productive capacity we now have branch offices in four major cities and two new ones about to be opened. In **1948** as in **1943**, we look forward, with your help, to a future busy with new silicone products and to a plant several times the size of our present one.

*TRADEMARK FOR DOW CORNING SILICONE RUBBER

DOW CORNING CORPORATION
MIDLAND, MICHIGAN
New York • Chicago • Cleveland • Los Angeles
Toronto • London • Paris • Stockholm • Oslo

Dow Corning
FIRST IN SILICONES

ceivers, by Orin Dakin of Canadian General Electric Co. Ltd.
Theatre Television Systems, by H. Goldin of Gaumont-Kalee Ltd.

Papers will be presented during the technical sessions each morning and afternoon. A banquet to be held on Friday, April 30, will have B. E. Shackelford, IRE president, as guest speaker.

BUSINESS NEWS

C. K. WILLIAMS & Co. is the new firm name of the Geo. S. Mepham Corp. of East St. Louis, Ill. The company continues to manufacture magnetic iron powders.

KAAR ENGINEERING CO., manufacturers of radiotelephones and marine direction finders, recently moved into a 35,000-sq ft building in Palo Alto, California, which

New Kaar plant

permits doubling production capacity. Kaar equipment will also be manufactured in Canada under a new agreement with Measurement Engineering, Ltd., Toronto.

ALLIS-CHALMERS MFG. CO., supplementing its regular line of electronic heating equipment, is now distributor for RCA h-f heating equipment and metal detectors.

NATIONAL RESEARCH CORP., manufacturers of high-vacuum apparatus, recently moved into its new

New plant of National Research Corp.

three-story building at 70 Memorial Drive, Cambridge, Mass.

SYLVANIA ELECTRIC PRODUCTS, INC. has acquired an interest in Thorn Electrical Industries Ltd. of Lon-

THESE EXTRA SMALL COIL FORMS FIT INTO TIGHT PLACES

Graphs show frequency ranges covered by the five standard sizes of LSM and LS3 Coils. Write for full-size copies.

If small space is your problem — as in peaking coils in strip amplifiers, chokes, R. F. coils, oscillator coils, single-turned I. F. coils, etc.—you'll find space-saving one of many advantages in CTC Slug Tuned Coil Forms.

Coil forms are of quality paper-base phenolic, high frequency grade. Mounting bushings and ring-type terminals are brass, the bushings cadmium plated and terminals silver plated. Necessary mounting hardware is supplied.

DIMENSIONS

LSM — Extreme small size; only 27/32" high when mounted; coil form, ¼" diameter; mounts in single #18 hole; mounting bushing has 8-32 thread.

LS3 — Moderate small size; 1⅛" high when mounted; coil form, ⅜" diameter; mounts in single ¼ hole; mounting has ¼-28 thread.

WINDINGS

CTC LSM and LS3 Coil Forms are available unwound or in any of five standard windings: 1, 5, 10, 30 and 60 megacycles. They are also wound to specifications. (Standard slug is high-frequency type.) CTC will custom-engineer special coils of practically any size and winding . . . Let us talk over your requirements.

CAMBRIDGE THERMIONIC CORPORATION
437 Concord Avenue, Cambridge 38, Mass.

BAACH-INTERNATIONAL
COMPOUND
HIGH VACUUM PUMP

This high vacuum pump is widely known and used extensively in the manufacture of electric lamps, radio tubes, fluorescent lamps, for laboratory work and for many industrial applications where high vacuum, plus rapid exhausting are essential requirements in processes of manufacturing.

In free air capacities ranging from 1 cubic foot to 50 cubic feet per minute.

Readings on all sizes guaranteed 0.50 microns or better.

Operates quietly. Prompt deliveries

Write for details.

INTERNATIONAL MACHINE WORKS

Manufacturers of Baach-International Hot Cut Flare machine.

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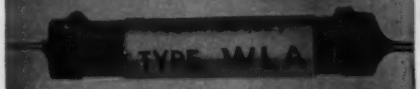
Tel. UNion 3-7412
Cable Address "INTERMACH" North Bergen, N. J.

IN-RES-CO
WIRE WOUND
RESISTORS

WL 5/8—5/8" x 3/16" (Radial Lead) .01 Ohms min. 3,000 Ohms max.
WLA 5/8—5/8" x 3/16" (Axial Lead) .01 Ohms min. 3,000 Ohms max.



WL—1" x 3/16" (Radial Lead) .01 Ohms min.
WLA—1" x 3/16" (Axial Lead) 10,000 max.

New Economy Line!

Here's a new line of resistors priced for real economy. Wire wound to a tolerance of 1% — higher accuracy on special order at slightly higher cost. Write today.

INSTRUMENT RESISTORS CO.

1036 COMMERCE AVE.
UNION, NEW JERSEY

APPLICATION-DESIGNED RESISTORS

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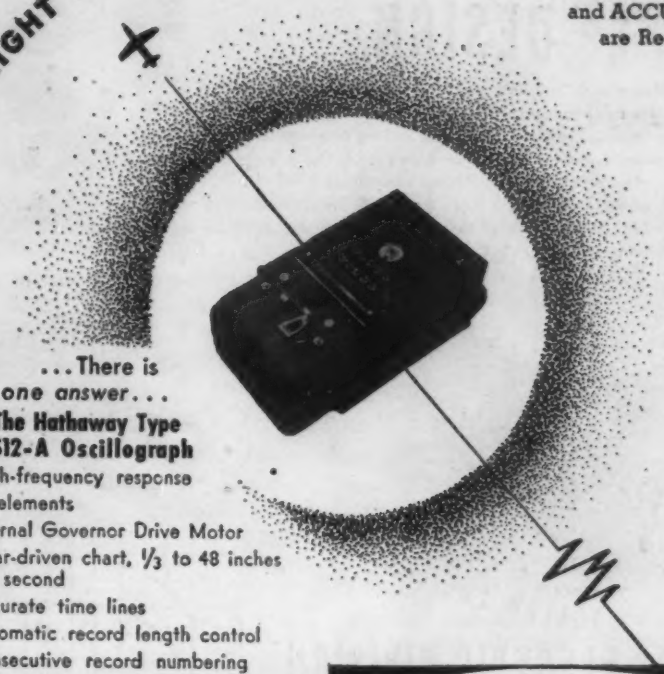
for

FLIGHT RESEARCH

...For all high-speed Recording requirements where PORTABILITY and ACCURACY are Required!



...There is only *one answer*...

The Hathaway Type S12-A Oscillograph

- High-frequency response
- 12 elements
- Internal Governor Drive Motor
- Gear-driven chart, 1/3 to 48 inches per second
- Accurate time lines
- Automatic record length control
- Consecutive record numbering

SIMPLE TO OPERATE
SMALL•LIGHT-WEIGHT
WRITE FOR BULLETIN SP 167-A

Hathaway
INSTRUMENT COMPANY
1315 SO. CLARKSON STREET • DENVER 10, COLORADO

COMPOUNDS

Scientifically compounded for specific applications from waxes, resins, asphalts, pitches, oils, and minerals. Available in wide range of melting points and hardnesses. Special potting compounds are heat conducting and crack resistant at extremely low temperatures. Recommendations, specific data, and samples will be furnished on request.

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radio coils
transformer coils
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SEALING
condensers
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Radio Transformers
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BIWAX CORPORATION

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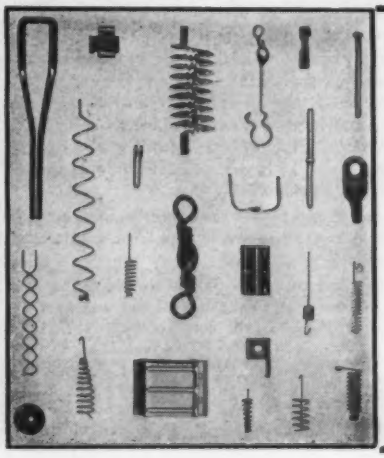


SMALL PARTS

Filaments, anodes, supports, springs, etc. for electronic tubes. Small wire and flat metal formed parts to your prints for your assemblies. Double pointed pins. Wire straightened and cut diameter up to ¼ inch. Any length up to 12 feet.

LUXON fishing tackle accessories.

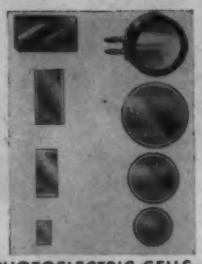
Inquiries will receive prompt attention.

ART WIRE AND STAMPING CO.

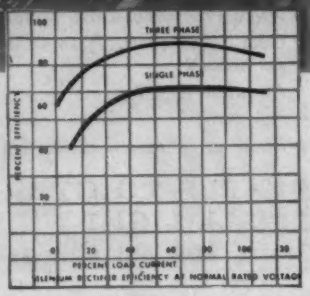
227 High St. Newark 2, N. J.

LINKING FUNCTION
TO DESIGN

Engineers and Designers who insist on dependable components have adapted Vickers Selenium Rectifiers into their circuits. They are specifying Vickers products, and are submitting their rectifier problems to us. Our greatly expanded plant facilities, plus the recognized dependability of Vickers products, make it possible for us to offer the most complete line of Selenium Rectifiers and self-generating Photoelectric Cells.



PHOTOELECTRIC CELLS



3-1

VICKERS ELECTRIC DIVISION

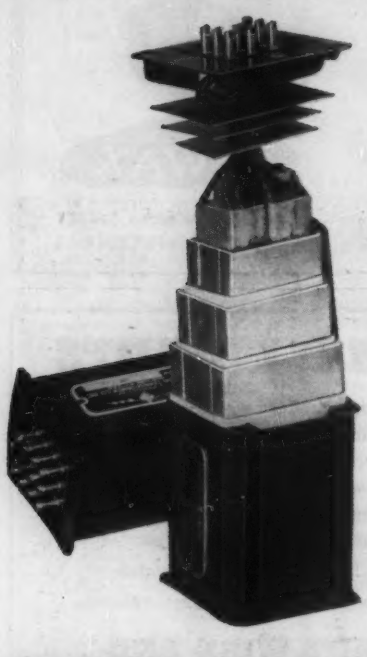
VICKERS INC.

2160 EAST IMPERIAL HIGHWAY • EL SEGUNDO, CALIF.

EXPORT: Frazar & Hansen, Ltd., 301 Clay St., San Francisco 11, Calif.
CANADA: Powertronic Equipment Ltd., 494 King St., E. Toronto 2, Canada

FOR LOW HUM..
HIGH FIDELITY

SPECIFY KENYON TELESCOPIC SHIELDED HUMBUCKING TRANSFORMERS



For low hum and high fidelity Kenyon telescoping shield transformers practically eliminate hum pick-up wherever high quality sound applications are required.

CHECK THESE ADVANTAGES

- LOW HUM PICK-UP . . . Assures high gain with minimum hum in high fidelity systems.
- HIGH FIDELITY . . . Frequency response flat within ± 1 db from 30 to 20,000 cycles.
- DIFFERENT HUM RATIOS . . . Degrees of hum reduction with P-200 series ranges from 50 db to 90 db below input level . . . made possible by unique humbucking coil construction plus multiple high efficiency electromagnetic shields.
- QUALITY DESIGN . . . Electrostatic shielding between windings.
- WIDE INPUT IMPEDENCE MATCHING RANGE.
- EXCELLENT OVERALL PERFORMANCE . . . Rugged construction, lightweight - mounts on either end.
- SAVES TIME . . . In design . . . in trouble shooting . . . in production.

Our standard line will save you time and money. Send for our catalog for complete technical data on specific types.

For any iron cored component problems that are off the beaten track, consult with our engineering department. No obligation, of course.

KENYON TRANSFORMER CO., Inc.
840 BARRY STREET NEW YORK, U. S. A.

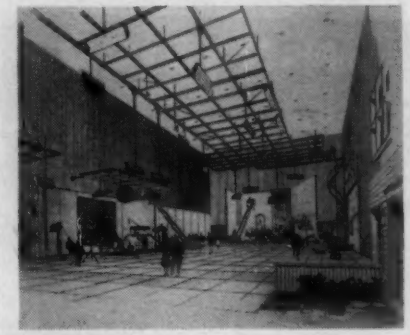
don, England, manufacturer of lamps, lighting products and radio sets.

THE YANKEE NETWORK of Boston, Mass., has the exclusive New England franchise for Transit Radio, Inc., a company organized to develop and perfect f-m receivers for surface transportation systems.

ELECTRICAL REACTANCE CORP., Franklinville, N. Y., manufacturers of high-Q components, will soon open a Canadian plant at Prescott, Ontario.

THE YMCA TRADE AND TECHNICAL SCHOOL of New York City now has courses in television and f-m radio set servicing and installation added to its curriculum. Courses will be given in the radio laboratories of Walter Hervey Junior College, New York City.

COLUMBIA BROADCASTING SYSTEM is now building the largest television studio plant in the U. S. as part of its plans to establish nationwide television service. The new



Artist's conception of one of main studios in new television studio plant

studios and their associated facilities occupy more than 700,000 cubic feet in New York's Grand Central Terminal Building.

SYLVANIA ELECTRIC PRODUCTS INC., New York City, has doubled production floor area to handle the manufacture of large television viewing tubes.

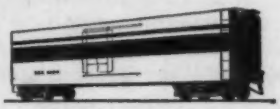
AMERICAN STANDARDS ASSOCIATION has issued the fifth edition of the Specification for Dry Cells and Batteries, known as American Standard C18-1947. The 18-page booklet covers definitions, nomenclature, standard voltages of dry batteries,

All in one package!

You must have thought often of the mighty important role shipping plays in your business and private life, for you depend on shipping for practically everything you eat, wear or otherwise use . . .

We of Railway Express know how diverse shipping requirements can be. With the addition of hundreds of new express cars, motor vehicles and other equipment, we are building our service to meet every one of your transportation needs.

Such improvements, as well as rising maintenance and operating costs, have made higher charges inevitable—but these charges will aid us in making Railway Express the *high standard* shipping service for you and for all America.



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. . . Maintains 23,000 offices (there's one near your factory, office or home) . . . Uses 10,000 passenger trains daily . . . Has 18,000 motor vehicles in its pick-up and delivery services . . . Offers *extra-fast* Air Express with direct service to 1,078 cities and towns.

RAILWAY EXPRESS AGENCY

NATION-WIDE RAIL-AIR SERVICE

standard sizes, markings, terminals, tests, and performance requirements. Copies may be obtained from the ASA, 70 E. 45th St., New York, N. Y., at a cost of ten cents.

DON FOSTER, INC., Cincinnati, Ohio, has been formed to engage in maintenance and servicing of electronic equipment. It will specialize in the installation of television, radiotelephone and medical equipment.

GENERAL ELECTRIC CO. now operates a new radio set manufacturing plant at Clyde, N. Y.

ALTEC SERVICE CORP., New York City, formed a decade ago to service and install sound equipment in motion picture theatres, has expanded its operations to include servicing of industrial electronic equipment in manufacturing and processing plants.

RAYTHEON MFG. CO., Waltham, Mass., has announced a new line of television station equipment including low and high-power transmitters, as well as portable camera chain equipment.

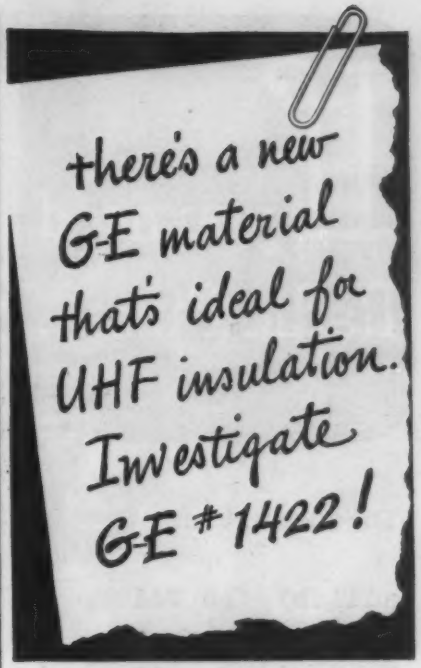
PERSONNEL

JOHN M. RICHARDSON has been named sales manager of the recording wire division of Spencer Wire Co., West Brookfield, Mass. During the war he was with Sperry Gyroscope Co. and the MIT Radiation Laboratory as a radar engineer.

J. M. Richardson

J. F. McAllister

JOHN F. M. MCALLISTER has been appointed designing engineer of the specialty division of General Electric Co. at Electronics Park, Syracuse, N. Y. He has been with the company since 1939, four years being spent teaching advanced



HERE'S A NEW MATERIAL that can cut costs and ease production problems wherever ultra-high-frequency insulation is required. It's G-E #1422 . . . a new development in plastics.

LOWER COST

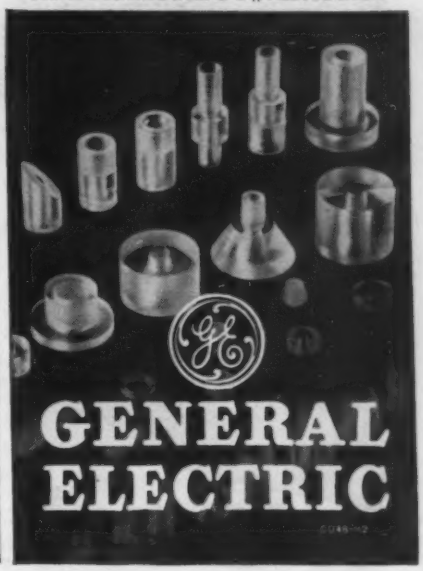
G-E #1422 answers the need for a low-cost material for structural components in ultra-high-frequency equipment. Use G-E #1422 where a low power factor is required . . . where high operating temperatures prevent the use of commercially available materials such as polystyrene.

EASY TO MACHINE

G-E #1422 can easily be machined. And it's available in rod or plate stock.

Send for more technical data. Write Section AF-5, Chemical Department, General Electric Company, Pittsfield, Massachusetts.

Connector beads for RG type coaxial cables machined from G-E #1422 rod stock.

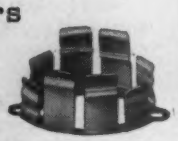


GENERAL ELECTRIC

If you need Radio Parts...

in quantities suitable to Volume Production...it may pay you to call upon the Design Engineers of United-Carr and its

subsidiaries. They have helped many manufacturers



★ CUT COSTS
★ SPEED PRODUCTION
★ TURN OUT FINER FINISHED PRODUCTS

UNITED-CARR FASTENER Corp.
CAMBRIDGE 42, MASSACHUSETTS
MAKERS OF DOT FASTENERS

radio and radar engineering courses at the Schenectady plant. For six months in 1945 he was in charge of electronic remote control equipment for V-2 rockets at White Sands, New Mexico.

LEOPOLD M. KAY has been promoted from chief engineer to vice-president in charge of engineering at Air King Products Co., Inc., Brooklyn, N. Y.

GEORGE F. PLATTS recently became executive vice-president of Clippard Instrument Laboratory, Inc., Cincinnati, Ohio. During World War II he served as a naval officer in connection with the development of the proximity fuze.

J. E. HOBSON, formerly director of the Armour Research Foundation of the Illinois Institute of Technology, has been appointed director of the Stanford University Research Institute. He received the Eta Kappa Nu award in 1940 as the outstanding young electrical engineer of the U. S., and in 1942 co-authored the book "Power Transmission and Distribution."

J. E. Hobson

R. E. Dorrell

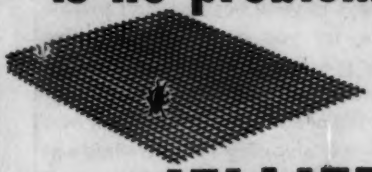
RUSSELL E. DORRELL, formerly with Naval Research Laboratory, was recently appointed to the staff of the National Bureau of Standards. He has joined the Electron Tube Laboratory as an electronics engineer working on test methods and equipment for evaluating tube performance.

NORMAN B. KRIM is the newly appointed manager of the receiving tube division of Raytheon Mfg. Co., in Newton, Mass.

DAVID R. HULL, Captain U. S. N. (retired), has been appointed assistant technical director of the International Telephone and Tele-

MESH SIZE

is no problem



for JELLIFF

For quality wire mesh — contact Jelliff — makers of wire mesh products for over sixty years. Commercial sizes available in standard lengths of 100 feet and widths of 24 to 72 inches. Meshes of specified gauge and weave made and cut to order. Available crimped, calendered and rolled. Jelliff engineers keep abreast of current developments in new alloys, coatings and processes and apply them when studying your requirements. For best results and maximum economies, look to Jelliff.

Write DEPT. L-201 For Literature

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SOUTHPORT, CONN.
WIRE PRODUCTS SINCE 1850
WIRE MESH • DIPPING BASKETS • LEKTROMESH • RESISTANCE WIRE • SCREENS • PARTS • WIRE CLOTH • STRAINERS

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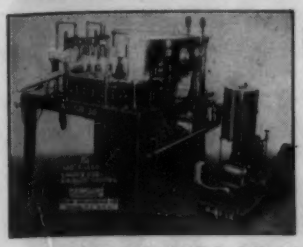
ELECTRICAL & ELECTRONIC
EQUIPMENT
ELECTRONIC TUBE EQUIPMENT



36 HEAD RADIO TUBE EXHAUSTING MACHINE

●

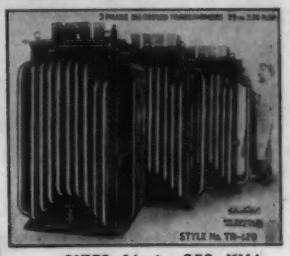
We Make Complete Equipment For The Manufacture Of Incandescent Lamps Radio and Electronic Tubes.

TRANSFORMERS OF ALL TYPES

For LIGHTING POWER FURNACES PHASE CHANGING DISTRIBUTION ETC.

●

Air, Oil, or Water Cooled



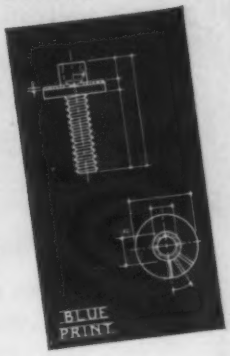
SIZES ¼ to 250 KVA

SPOT WELDERS
OF ALL TYPES
FOR ALL PURPOSES
SIZES ¼ to 250 KVA

Butt Welders - Gun Welders
Arc Welders
Neon Sign Units
Fluorescent Tube
Manufacturing Equipment

CHAS. EISLER
EISLER ENGINEERING CO., INC.
751 So. 13th St. (Near Avon Ave.), Newark 3, N. J.

ANOTHER SPECIAL BY PROGRESSIVE



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Special heads, threads and finishes on any metal or alloy adapted to cold upset. Weekly output: 25,000,000 pieces. Many specials, suggesting production savings for you, illustrated in latest catalog. Includes weights per 1M standard pieces, dec. equivs. of fractions, other purchasing and engineering helps. Write for Catalog 19.

The PROGRESSIVE MFG. CO.
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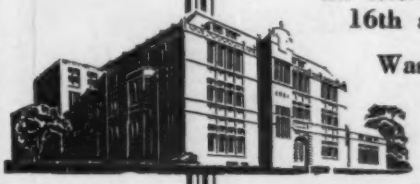
METAL MERCHANDISERS SELL your product CONSTANTLY!

These "silent salesmen" are on the job always . . . creating a desire for your product at the point of sale. Any size, shape or design can be created for you by our master designing department. We have 36 years of "know-how" and have created metal products and displays for the top manufacturers.

Write today for descriptive folder.

CENTRAL
Sheet Metal Works, Inc.
2645-49 Clybourn Ave.
Chicago 14, Ill.

"Where Professional Radiomen Study"



CAPITOL RADIO ENGINEERING INSTITUTE
An Accredited Technical Institute
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graph Corp. From 1933 to 1940 he directed navy research activity in sonar and radar. As assistant chief of the Bureau of Ships for Electronics he was responsible for the entire navy electronic program.

D. R. Hull

W. B. Haliday

WILLIAM B. HALIDAY, previously with the physics department of the University of Minnesota and with the Naval Research Laboratory, was appointed engineer in charge of model tube construction at the Electron Tube Laboratory of the National Bureau of Standards.

A. M. SKELLETT has advanced from chief engineer and director of research to vice-president in charge of the research division of National Union Radio Corp., Orange, N. J. He previously spent fifteen years as a member of Bell Telephone Laboratories' technical staff.

A. M. Skellett

D. T. Ferrier

DAVID T. FERRIER, formerly navy liaison officer at the MIT Radiation Laboratory and at the Radio Research Laboratory of Harvard U., is now assistant to president at Servo Corp. of America, Lindenhurst, New York.

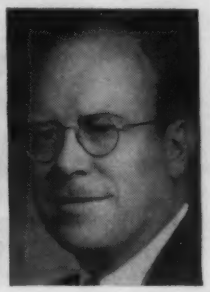
OTIS S. FREEMAN, with television station WABD for four years as chief operating engineer, has joined the engineering staff as assistant for operations of WPIX, the News

television station, New York City. Station WPIX is scheduled to go on the air June 15 on Channel 11.

DWIGHT J. EVANS has joined Branson Instruments, Inc., Danbury, Conn., as chief engineer in charge of the development of new instruments for the processing industries.

ERIC R. BERGLUND was recently named vice-president in charge of management and engineering of Intercontinent Engineering Corp., New York City, which specializes in engineering work for foreign countries, chiefly communications and radio aids to navigation. He was formerly television facilities engineer at NBC for ten years. Previous to this he was radio and television engineer for RCA and Westinghouse Electric Co.

E. R. Berglund



J. A. Hutcheson

JOHN A. HUTCHESON has been appointed director of the Westinghouse Research Laboratories. During the past four years he directed the company's wartime radar research program and later the formulation of plans for atomic energy development.

HALDON A. LEEDY, chairman of physics research since 1944, has just been named acting director at Armour Research Foundation of Illinois Institute of Technology. During the war he was active in the foundation research program on magnetic wire recording.

DALE POLLACK, consulting radio engineer of New London, Conn., has been appointed research associate in the department of applied mathematics of the Weizmann Institute of Science at Rehovoth, Palestine. He was previously associated with RCA, Bell Telephone Laboratories, and Templetone Radio Mfg. Corp.

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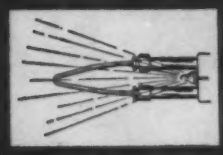

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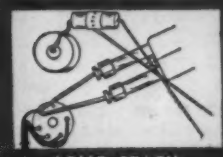

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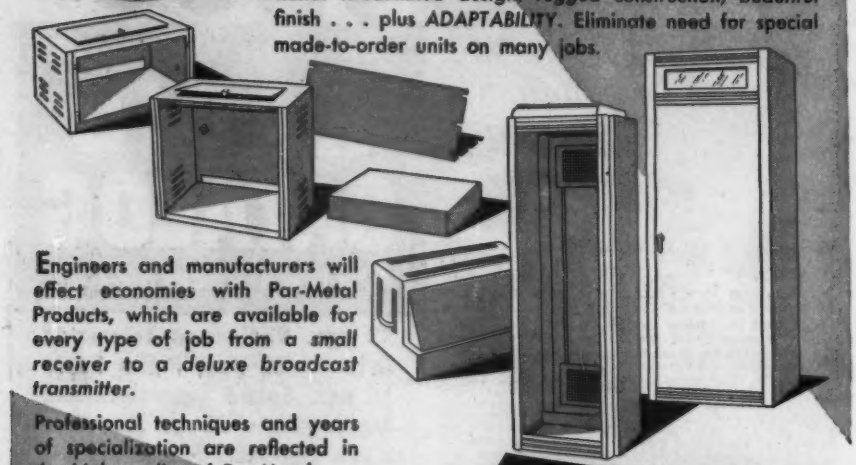

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NEW BOOKS

Theory of Servomechanisms

Volume 25 of the MIT Radiation Laboratory Series. EDITED BY HUBERT M. JAMES, NATHANIEL B. NICHOLS, AND RALPH S. PHILLIPS. *McGraw-Hill Book Company*, 1947, 375 *pages*, $5.00.

"IT IS nearly as hard for practitioners of the servo art to agree on the definition of a servo as it is for a group of theologians to agree on the definition of sin."

This beguiling and justifiable sentence opens a treatise on servomechanisms which is several times more ambitious and more advanced than any which has thus far been published. It is based principally on the intensive studies and developments carried out at MIT Radiation Laboratory during World War II. The general presentation can best be indicated and accounted for by noting that all the authors are mathematically articulate and that two of them are recognized as mathematicians of parts.

On the other hand, much practical and detailed data are given of servo components, and such extremes typify the book's large scope. But it is bound to be a rude shock to most practitioners to come upon the Parseval theorem and Laguerre functions in company with spur-gear trains, discriminator circuits, and manufacturer's data on synchros and motors.

Speaking generally, this treatment rephrases, applies, and extends the fundamental work of Brown, Harris, and Hall on servomechanisms, and is influenced considerably by that of Black, Guilleman, Bode, and Wiener in the allied field of communication networks. Compiled out of several contributions covering many phases of the subject, the book needed much coordinating editorial work to achieve unity. It is evident that this work was not only conscientiously done, but that it was applied at an early stage.

Following an introductory discussion of servo systems, an unusually thorough presentation is included of the mathematical background behind the modern usages of transfer loci and stability criteria. Notable as a departure, and

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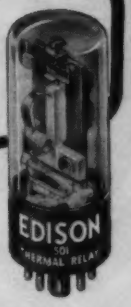

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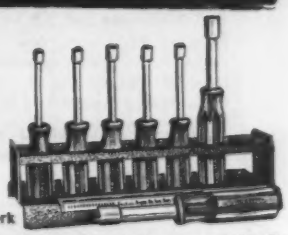

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of significance for the rest of the book, is the concept of weighting function. For any linear filter, the relation of the input x_1 to the output x_2 is given by the convolution integral

$$x_2 = \int_0^t W(t - t')\, x_1(t)\, dt'$$

where the weighting function $W(t)$ is the response of the filter to a unit pulse. Incidentally, an unusual covention is adopted in writing integrals: all integrands are placed after the differential. This practice might be found acceptable in general, particularly from the standpoint of symbolic operators.

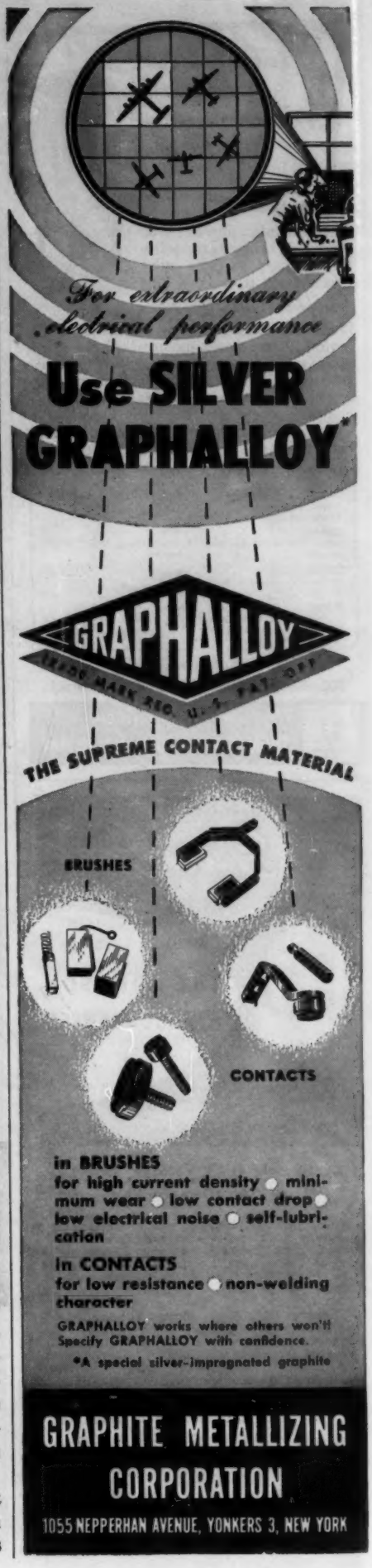
Next come servo elements, including error sensors, repeater and transmitter components, modulators, discriminators, gear trains and motors. Much new material is included, and some in surprising detail. Correcting networks are discussed for both a-c and d-c signals. Naturally the choice of components is limited to those most significant for radar systems.

A chapter of 90 pages covers general design principles. The engineering techniques now in use are given through a review of the available methods of analysis (leading to application of decibel-log-frequency and decibel-phase charts), and covering multiple-loop as well as single-loop systems (leading finally to practical examples in the SCR-584 radar with amplidynes, and also in servos with two-phase motors).

New theories are given on servos fed with pulsed data, and on the employment of filters with clamping. The revised stability criteria are elegantly derived, and the analogy with continuous servo theory very effectively brought out.

A fundamental presentation is included of the statistics of random processes, with applications to the problems of noise and fading in servo design. There is also a thorough demonstration of the new minimum-rms-error criterion, augmented by a table of definite integrals of special type for computation in the case of systems up to the 8th order. A final chapter applies many of the above design techniques to typical problems.

It is mild criticism to point out that this book, which contains much that has been unavailable, follows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most other servo literature in two respects. First, many pages are devoted to material which applies far more generally than to the closed loop structures of the servomechanist or of automatic controls generally. Secondly it is almost exclusively concerned with the linear theories. The simplest control law of all, for example, that of the on-off regulator, is basically nonlinear, and high-performance servos of this type have been developed and described by both British and American groups. But the substantial omission of inherently nonlinear systems, and of tools such as analog devices for their study and development, simply indicates pioneering directions for the future.

The authors and editors must be congratulated on their handling of a large and difficult task. As to the publication itself, relatively few errors have been discovered in typesetting or proofreading. This volume will remain within easy reach in the library of the present reviewer.—GEORGE A. PHILBRICK, *research consultant, The Foxboro Co., Foxboro, Mass., and president, George A. Philbrick Researches, Inc., Boston, Mass.*

Theory and Application Of Microwaves

BY ARTHUR B. BRONWELL AND ROBERT E. BEAM, *Northwestern University. McGraw-Hill Book Co. Inc., New York, N. Y.*, 1947, 470 *pages*, $6.00.

THE NEED for a single book combining the essential information on microwave tubes, transmission, and propagation is well filled by this new text. Although the book is predominantly theoretical, the authors have succeeded in their goal of simplifying the presentation and expressing the results in a form convenient for engineering use. MKS units are used throughout the text.

The fundamental laws of electron motion are reviewed as a preliminary step in the analysis of microwave tubes. These basic concepts are then applied to the analysis of negative-grid triodes, Barkhausen oscillators, klystrons, and magnetrons. Discussion of resnatrons and traveling-wave tubes is also included. Transmission lines are in-

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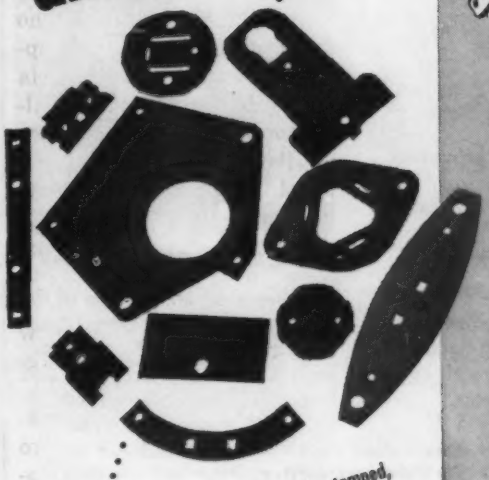

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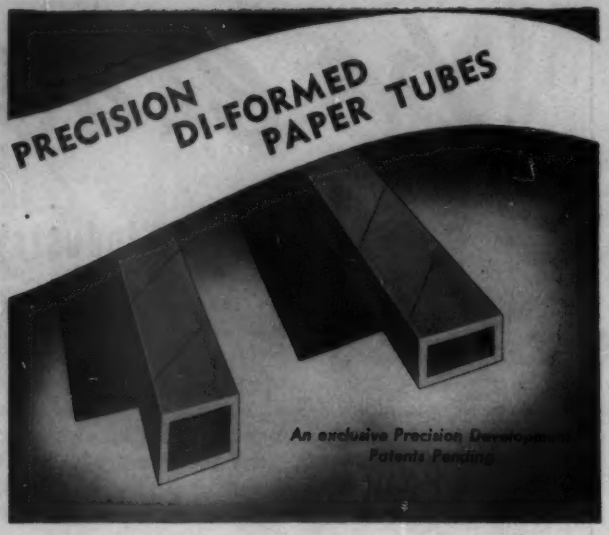

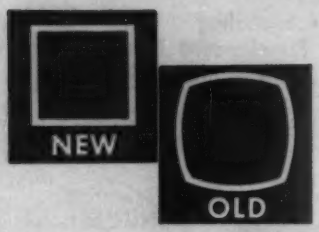

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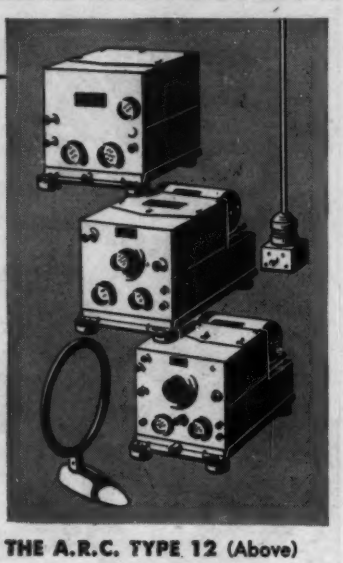

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troduced in the conventional manner, but the application to microwave problems is stressed and the graphical solution of problems is emphasized. The chapters on microwave systems briefly describe the combination of these principles with low-frequency practice.

A more advanced level of analysis using Maxwell's equations has been adopted in the last chapters of the book. An analysis of wave guides and cavity resonators is followed by material on the application of these devices. Theoretical material predominates in the final chapters on antennas and radiation.

Although the book was prepared for senior and graduate students in electrical engineering at the present time, it will prove particularly attractive to engineers who graduated before this wealth of material became available. The numerous problems will be equally valuable to students and engineers reviewing this field. Whether they are engaged in microwave relaying or not, most engineers will find this combination of simplicity and broad coverage of the field ideal.

There are few criticisms to offer. Some mistakes do occur, but they are often of the type that will be recognized readily by the reader. More adequate discussion of grounded-grid amplifiers and paraboloidal antennas should have been included, and a greater number of references would be desirable.—A. E. HARRISON, *Princeton University, Princeton, N. J.*

High Vacua

BY SWAMI JNANANANDA, *Randall Laboratory of Physics, University of Michigan. D. Van Nostrand Company, Inc., New York, N. Y.*, 1947, 310 *pages*, $5.50.

THE FIRST portion of this book contains a useful review of gas laws, kinetic theory, and free path phenomenon. Tables are included with information on mean free path, rates of evaporation, coefficients of viscosity, thermal conductivity, and other information of general value to workers concerned with flow of gases and vapors at low pressures.

The information on the production and measurement of high vacua is entirely restricted to reviews of early workers in the field and is pri-

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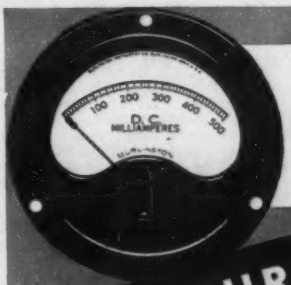

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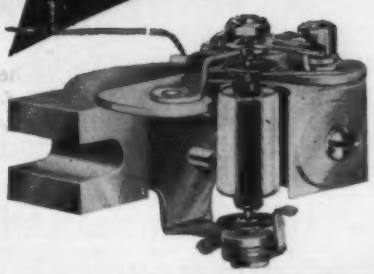

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marily an early historical treatment of the art. The author has drawn heavily upon the early books and articles, many of which were published prior to 1930. As a compilation of the early development of diffusion pumps and gages, the book will find a useful purpose, but as an aid to physicists or engineers familiar with developments in vacuum technology during the past ten years, it will be found of very little value.

In describing the possibility of employing metal as a construction material, the author states: "systems can also be made from plates and cylinders of yellow brass, screwed together and rendered vacuum-tight by a fine coating of beeswax and rosin mixture on the outside to close the intervening cavities and leaks." This approach to the problems of high vacuum engineering, which have advanced so rapidly during the war years, is indicative of the type of information to be found in this volume. —RICHARD S. MORSE, *president, National Research Corporation, Cambridge, Mass.*

Books Received for Review

PREPARING FOR FEDERAL RADIO OPERATOR EXAMINATIONS. By Arnold Shostak. Prentice-Hall Inc., New York, 1948, 404 pages, $3.75. Answers to questions in FCC Study Guide, for students preparing to pass any or all of the six classes of examination elements. Diagrams do not follow ASA symbol standards. New f-m and television questions are not covered.

RADIO RECEIVER TUBE PLACEMENT GUIDE. Compiled and published by Howard W. Sams & Co., Inc., Indianapolis, Ind., 1948, 192 pages, $1.25. Collection of top-of-chassis diagrams showing placement of tubes in approximately 5,400 radio receivers manufactured between 1938 and 1947.

FRACTIONAL HORSEPOWER ELECTRIC MOTORS. By Cyril G. Veinott. McGraw-Hill Book Co., Inc., New York 1948, Second Edition, 554 pages, $5.00. Types available, operating principles, performance characteristics, and instructions for repairing, rewinding, and reconnecting. Eight chapters have been largely rewritten, and all others brought up to date.

PRACTICAL AMPLIFIER DIAGRAMS. By Jack Robin and Chester E. Lipman. Os-tronic Publications, 196 W. 37th Place, Los Angeles 7, Calif., 1947, 55 pages, $2.00. Spiral-bound collection of 23 audio-amplifier circuits with parts lists, plus 13 pages of general comments on amplifier servicing, reproduced from typed copy.

ELEMENTS OF RADIO. By Abraham and William Marcus. Prentice-Hall Inc., New York, 1948, Second Edition, 751 pages $4.25. Revised and expanded new edition of an elementary radio text that has sold over 500,000 copies (including military printings) since it came out in 1943. Intended for home study as well as radio school classroom use, covering principles of radio operation from crystal sets through modern superheterodynes and including questions and suggested classroom demonstrations for each chapter.

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Backtalk

This department is operated as an open forum where our readers may discuss problems of the electronics industry or comment upon articles which ELECTRONICS has published.

More Hartley Law

DEAR SIRS:

PUBLISHED accounts of the symposium on "Bandwidth vs Noise in Communication Systems" tend to obscure the fact that the Tuller-Shannon-Sullivan-Wiener-etc. law does not represent in fact a revision of the Hartley law; rather, the "new" law represents a somewhat more explicit formulation of the latter.

Hartley's law, as stated in his paper, can be expressed in the following form

$$C = 2W \log_M S \qquad (1)$$

where C is the capacity of the channel to carry information per unit time, W is the bandwidth of the channel, S is the number of what came to be known as quantum levels, and M is an arbitrary base of logarithms. Furthermore, as Hartley pointed out, in practice the number of quantum levels, and hence the capacity of the system, is limited by the distortion (random and non-random) introduced by the transmission channel.

A comparison of Eq. 1, with the expression for the "new" law which is

$$C = W \log_2 \left(1 + \frac{P}{N}\right) \qquad (2)$$

where P/N is the signal-noise ratio expressed in power units, shows that the "new" law could be obtained from Eq. 1 by the mere substitutions

$$S = \left(1 + \frac{P}{N}\right)^{\frac{1}{2}} \text{ and } M = 2$$

The fact that S is actually equal to $(1 + P/N)^{\frac{1}{2}}$ is readily deduced by the following reasoning:

Under the condition of full use of the capacity of the transmission channel, separation between successive quantum levels is equal to $(N)^{\frac{1}{2}}$ while the total height of the levels

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is equal to $(P + N)^{\frac{1}{2}}$. Therefore the number of quantum levels is given by

$$S = \frac{(P+N)^{\frac{1}{2}}}{(N)^{\frac{1}{2}}} = \left(1 + \frac{P}{N}\right)^{\frac{1}{2}}$$

Thus, the "new" law can be obtained directly from Hartley's law through calculation of the maximum permissible number of quantum levels.

It should also be pointed out, that in the derivation of the "new" law it is tacitly assumed that the bandwidth of the transmission channel is at least as large as that of the message. Thus, statements to the effect that the "new" law indicates the possibility of transmitting speech on a bandwidth of only a few hundred cycles, are completely unfounded. True, it might be possible to do so by using a method of frequency compression described by D. Gabor in the November issue of the *Journal of I.E.E.*, but this and other similar schemes have nothing in common with the "new" law.

LOTFI A. ZADEH
Department of Electrical Engineering
Columbia University, New York

Gigacycles

DEAR SIRS: READING about the suggestion *kilomegacycle* in Cross talk, February ELECTRONICS, I cannot suppress my opinion that this term sounds stilted to me indeed.

May I remind you that the following abbreviations are shorter, printed in text books, and even used. The extreme ones are, of course, less known since the limited number of potential applications does not justify their use:

10^3 kilo	10^{-3} milli
10^6 mega	10^{-6} micro
10^9 giga	10^{-9} nano
10^{12} terra	10^{-12} pico

The new field of vhf, as pointed out, makes a new power-of-ten multiple highly desirable. So, why not be consistent and call it a *gigacycle?*

A similar, even more urgent, necessity exists for the subunit of 10^{-12} farad which is so commonly used in electronic work.

I have a small Bakelite molded condenser, it reads "00037". The decimal point is not easily found. You start counting the zeros in order to find out—after 15 to 30 sec, depending upon the mental alertness of the tested person—that this is most probably a condenser

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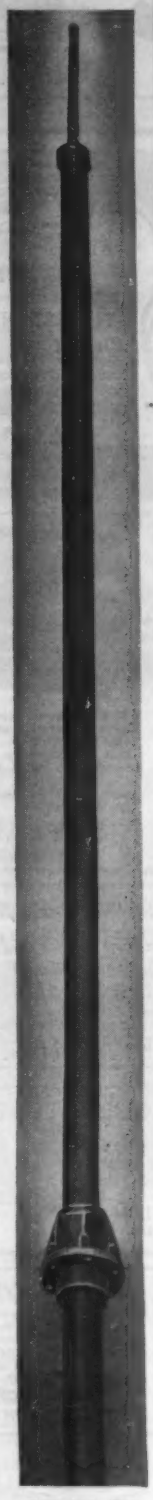

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of 370 pf, assuming that the missing decimal point usually proceeds the row of zeros and that the value of its capacity is given in μf.

Within the same space the manufacturer might have printed the above given abbreviation, and would have been explicit.

The word *pico* is used as my information goes, in printing, meaning a twelve-point letter, and is supposed to be taken from medieval Latin. It has the definite advantage over the $\mu\mu$f that it is shorter and can be typed on any typewriter. The latter obstacle leads to the abbreviation mmf, which is outright faulty, since m stands for *milli*.

Electronics is the one branch of industry (known to me), where the metric system has beaten the British System of Units. At least, I do not expect the change from wavelengths in meters and centimeters into feet and inches in the near future—even, if the convenience of the frequency-wavelength conversion should prove to be the sole shield against such a change.

Your magazine is the outstanding representant in its field. That means educational responsibilities are nolens-volens conferred upon it; and it is in this particular sense, when I say that I appreciate Mr. McGraw's excellent articles very much, indeed.

Assume that your magazine would pursue the ultimate goal—a complete conversion from British to Metric Units—a part of its policy. More optimistically, assume the change can be accomplished within a hundred years from now.

Just realize the obtained increase in learning efficiency for the lucky student of nucleonic industry of that age. It doesn't take too much imagination that, by that time, he will need the amount of saved time for more productive studies in order to become a useful member of the more and more complex industrial machine. . .

And it should be timely also at a moment when all former international Electric Units are officially dropped and the new ones rebased on the fundamental metric units of mass, length, and time.

HORST M. SCHILLBACH
Assistant Professor in Physics
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200 mhy.	HQA-8	9.00	12 hy.	HQB-10	22.00
300 mhy.	HQA-9	10.00	18 hy.	HQB-11	23.00
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VIC-5	.053	11.00	VIC-15	5.4	16.50
VIC-6	.084	11.00	VIC-16	8.5	16.50
VIC-7	.13	14.00	VIC-17	13	16.50
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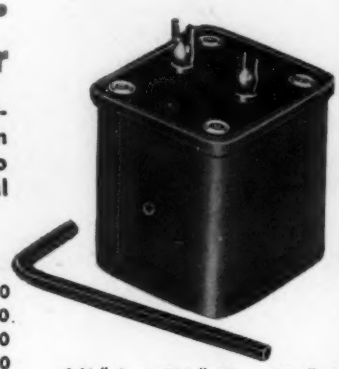

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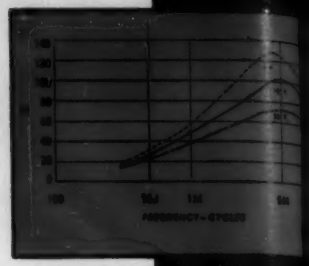

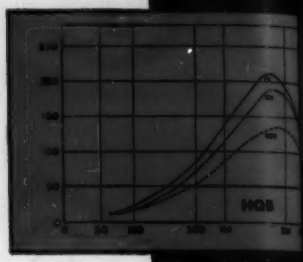

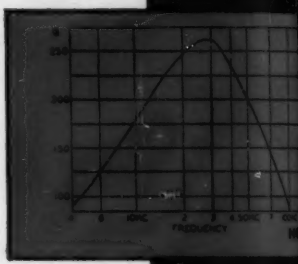

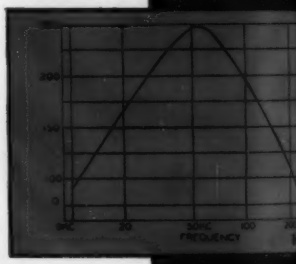

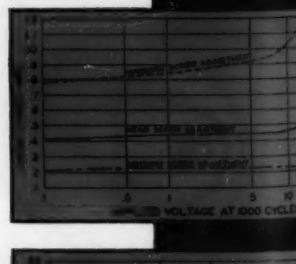

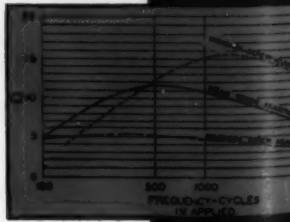

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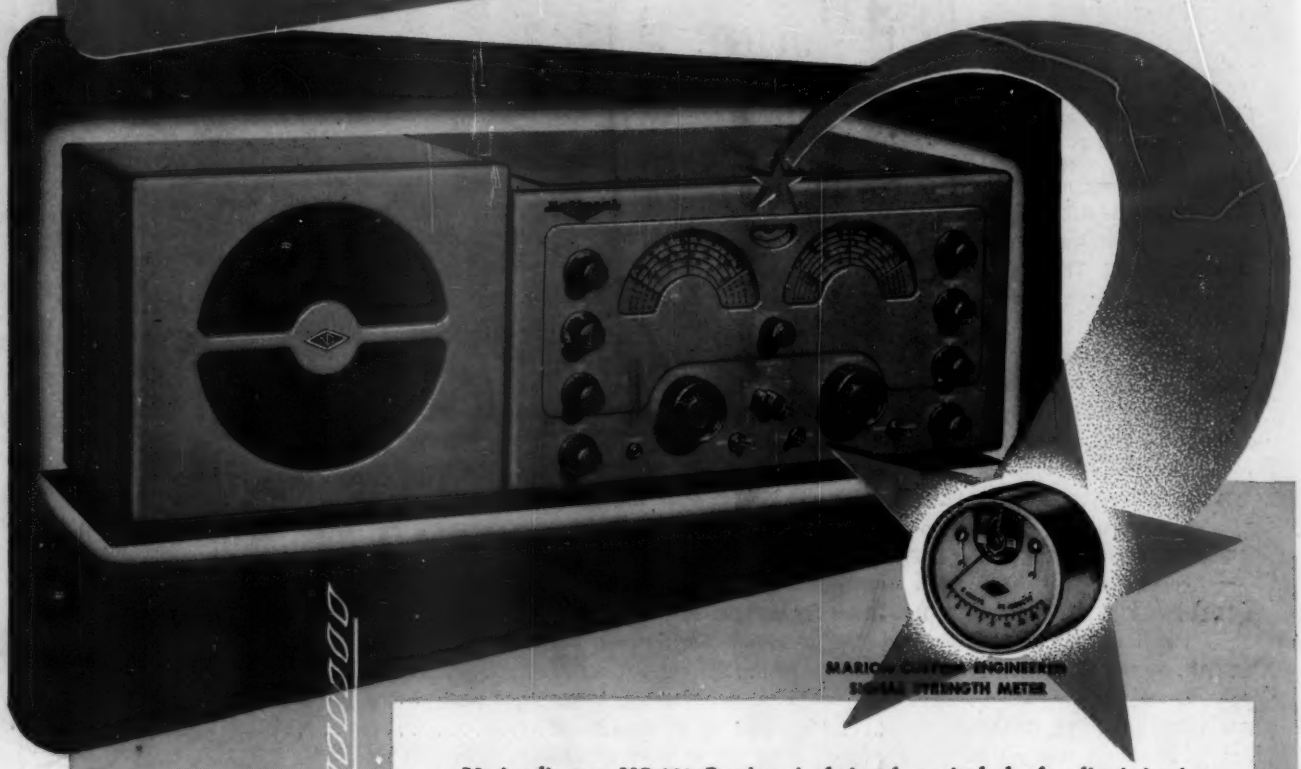

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